No. 3.— *Expedition to the Baltic Provinces of Russia and Scandinavia, 1914.*

Part 1.— The Correlation of the Ordovician Strata of the Baltic Basin with those of Eastern North America.

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TABLE OF CONTENTS.

PREFACE.

The writer has been engaged since the summer of 1900, in the study of the stratigraphy and faunas of the Middle Ordovician formations of the northeastern United States and Canada. During all that time the need of a personal knowledge of the Ordovician strata of northern Europe had become more pressing, so that he was exceedingly glad of a grant from the Shaler Memorial fund which enabled him to spend several months of the summer of 1914 in Russia and Scandinavia. With the coöperation of Dr. W. H. Twenhofel, who studied especially the Upper Ordovician and Silurian strata, a rather complete, though necessarily hasty survey of the Lower Palaeozoic strata of the districts mentioned was completed between May 1 and September 30 of 1914, and large collections secured. The outbreak of the war interfered with the completion of the work as planned, and quite seriously affects the present report, since all the collections of three men during a month spent in Esthonia were in Russia at the time of the outbreak of hostilities and it is somewhat doubtful if they ever reach this country. Our conclusions on some points are therefore of a tentative nature, and if we should be so fortunate as to receive the collections, a supplementary report may be necessary.

The results of a trip of this sort are very largely dependent upon the assistance of others, and I have an unusually large number of courtesies to acknowledge. To my colleagues in the Division of Geology at Harvard University I am deeply indebted for making the expedition possible. To Prof. Charles Schuchert I owe much for advice, and for letters of introduction over a route which he had himself travelled. Mr. I. P. Tolmacev, Curator-in-chief of the Museum of the Imperial Academy of Science in Petrograd, made arrangements and secured letters which greatly facilitated our work in Russia. It was he, and the excellent assistant, Mr. Carl Lackschewitz, whom he secured to travel with us, who enabled us to work continuously and comfortably during our stay in Russia. Mr. Lackschewitz, a grandson of the celebrated Middendorf, and grand-nephew of Fr. Schmidt, in whose footsteps we were following, proved our invaluable interpreter, advisor, and business agent. To the knowledge and skill of Mr. O. Knyrko preparator at the Museum in Petrograd, I am indebted for much beautifully preserved material collected during the ten days in which he acted as guide in the region south of Lake Ladoga. To the many other gentlemen who assisted us in Russia, some of whom are named in the introduction to Dr. Twenhofel's report, I also wish to express my thanks.

Just as I write these acknowledgements comes the sad news of the death of Professor Dr. Johan Christian Moberg, but for whose kindly assistance my visit to Sweden would have been of little value. Cutting short his own field season, Professor Moberg devoted himself for almost three weeks to guiding me over the Cambrian and Silurian deposits of Scania. Without his intimate knowledge of the extremely restricted outcrops in this region, my work would have been fruitless, indeed, impossible in the restless moments of the first weeks of the war.

In Norway we were greatly indebted for guidance and hospitality to Professor Kiaer and Dr. Holtedahl who made possible a great deal of work and collecting in a very short time. Nor must I omit an expression of my obligation to M. Pierre Pruvost of Lille for escorting me during three pleasant days spent among the Palaeozoic outcrops of the Ardennes. It is with more than usual feeling that I make these expressions of sincere gratitude to those who assisted me, especially as there is only too much cause to fear that they may never see these lines.

Finally, I wish to express my appreciation of Dr. Twenhofel's kindness in undertaking his part of the work, and of his hearty coöperation in the field.

THE ORDOVICIAN STRATA IN THE GOVERNMENTS OF PETROGRAD AND ESTHONIA, RUSSIA.

Location.

The Cambrian and Ordovician strata of western Russia outcrop in the northern parts of the Governments of Esthonia and Petrograd, forming a narrow strip about 380 miles long, extending from the island of Dago along the southern shore of the Gulf of Finland to the eastern boundary of Esthonia at the Narowa River, thence eastward inland to the Sjass River, south of Lake Ladoga, and eighty-five miles east of Petrograd. This strip is roughly triangular, having at its widest portion in Esthonia, a breadth of thirty miles, and narrowing to a point a short distance east of the Sjass. In Esthonia, west from Lake Peipus, the Ordovician is followed by the Silurian; while in the Government of Petrograd, the Devonian conceals the Silurian and overlaps successively lower and lower beds of the Ordovician, until east of the Sjass, it conceals all but a narrow band of Cambrian. This overlap of the Devonian on the Ordovician in the Government of Petrograd does not, however, indicate at all the absence of Silurian in the southern part of that district, as many geologists have believed. Throughout the whole band, the older strata dip gently to the south, a dip which they apparently received in pre-Devonian times. Thus each successively higher stratum has its outcrop in an east-west band lying southward from its neighbor, and the Devonian, lying unconformably on these beds, conceals older and older ones according to the amount of its northward extent. (Plate **1**).

Previous work.

As early as 1821 an Englishman, William Strangways, (52), published a detailed description and map of the strata in the vicinity of Petrograd, and since then various writers have described in great detail the Cambrian, Ordovician, and Silurian of this region. The principal writers on the Geology, as distinguished from the Palaeontology, have been Murchison, (35), Eichwald, (8), Schmidt, (42, 44, 45, 47), Mickwitz, (33), and Lamansky, (29). Recently Bassler, (1), has published a short resumé of the results of the work of Schmidt and Lamansky.

The palaeontologists have been particularly active in describing the Ordovician fossils of this region, as may be seen by the very long list of species given by Bassler, (1). Part of this work, on the trilobites by Schmidt, (48), bryozoans by Bassler, (1), and cystids by Jaeckel, (24), is modern, as are also descriptions of certain groups of Ostracoda, Cephalopoda, Brachiopoda, and Gastropoda by various writers. The bulk of the Brachiopoda, Pelecypoda, and corals, still await monographic treatment, though some of these groups are now in the hands of specialists.

Object of the present paper.

Although so well known and fully described, there still exist in text-books many inaccurate statements about the region under discussion and there is no modern general treatment of the whole area. For these reasons, and because previous papers are mostly in German and Russian, and without illustration, there exists in the minds of most American geologists only a very vague idea of the character of the Russian deposits, and the writer therefore feels justified in retraversing this old and well-known ground, and hoping to add something to what has previously been observed.

During the seven weeks spent in this area I was able to cross the outcrop of the Cambrian and Ordovician on the Sjass, the Walchow, and the Lawa at Wassilkowa, all south of Lake Ladoga, at Papowka, south of Petrograd, at Narwa, from Ontika south to Jewe, from Port Kunda south through Wesenberg and Taps to Borkholm, from Reval and Baltishport southwest through Kegel, Wassalem and Lyckholm to Hapsal, and also visited the principal localities on the northern half of Dago. I was thus able to see all the principal sections and type-localities and crossed the Cambrian-Ordovician belt at right angles to the strike at frequent intervals throughout the whole length of the outcrop.

Although the Borkholm and Lyckholm are considered by the writer to belong to the Ordovician they are treated only incidentally in this paper, but are fully discussed by Dr. Twenhofel (Bull. M. C. Z. **56**, no. 4).

Nature of the exposures of the strata.

Throughout the whole area underlain by the Ordovician strata the country is comparatively flat, and the majority of the hills which do occur are composed of glacial debris. Along the whole northern boundary of the area there is an abrupt escarpment, facing northward, extending from the island of Odensholm through Baltishport and along the southern shore of the Gulf of Finland to the mouth of the Narowa, and thence across country south of Petrograd to the Sjass. Where this borders the sea it is usually very steep, often perpendicular or overhanging. In the Government of Petrograd it is a steep slope, but usually without exposures of rock except where cut by streams or by the opening of quarries. This cliff, or "Glint,"[1] is of variable height; only fifteen feet on Odensholm, it reaches its maximum height of 206 feet at Ontika in the eastern part of Esthonia, and probably averages 75 to 100 feet. The strata composing the top of this cliff are, remarkably enough, practically always the same, being the rather hard magnesian limestone of the lower part of zone C or the "Echinosphaerites" layers. Such being the case there are many excellent exposures of the part of the Ordovician below this horizon, and, where there is not too much talus at the foot of the cliff, the upper part of the Lower Cambrian is usually shown.

From Petrograd eastward, no strata of the Ordovician are exposed above the Echinosphaerites beds. The higher strata are to be found in the part of the Government of Petrograd west of the metropolis, and especially in the Government of Esthonia. These beds are very seldom seen in natural sections, being practically always uncovered only by the opening of quarries. All the quarries are of comparatively small extent and very shallow, so that there is never more than one formation exposed in any one quarry, and contacts between formations above the Kuckers have never been seen.

Over large areas in Esthonia the strata lie very close to the surface, and even very shallow ditches often penetrate the rock. Among such ditches the "Graben" on the estate of Baron Toll at Kuckers, near Jewe, is famous as the principal locality of the Kuckers formation. Many other ditches, often very small ones, were examined during this trip and often afforded the only outcrops over considerable areas.

Formational Names.

The names applied to the formations in this district of Russia bear a direct relation to the above described occurrence of outcrops. In the classification proposed by Schmidt the important divisions of the

[1] From the Danish Klint, a reminder of the settlement of this country by the Danes in the 12th century.

Cambrian and Ordovician were lettered in ascending order A to F, and many of the subdivisions designated by numbers as, C_1, C_2, C_3 and finally some of these subdivisions were further divided by Lamansky, as for instance $B_{II\alpha}$, $B_{II\beta}$ and $B_{II\gamma}$. The strata also received names suggested by their lithological characteristics or faunal contents, as for instance, B_I was also known as the "Glauconite sand" and B_{III} as the "Orthoceras limestone" or "Vaginatenkalk." The divisions from A to $C_{1\beta}$ are to be found in the escarpment, and these together received the collective name of the "Glint" but no formation in this part of the series has received a separate geographic name.

The strata above $C_{1\beta}$ are exposed as has already been explained, principally in quarries, and therefore each formation has received a name from the locality which has furnished either the best exposures or the best fossils. Thus C_2 is known as the Kuckers, E as the Wesenberg, etc.

In this particular case, both the system of lettering and the system of descriptive names is objectionable, and for the sake of uniformity the writer suggests a set of geographic names for the older formations of the series. The system of lettering fails, because A_2 and A_3 of Schmidt prove not to be Cambrian but Ordovician, thus splitting A between two great systems. There is likewise a difficulty about D_2 which will appear later. A mixed table of descriptive names, part derived from lithological and part from faunal characteristics is never satisfactory, and in this case the names seem particularly inapplicable. Thus the "Orthoceras" limestone is not by any means the only formation in Russia in which Orthoceras is abundant, and the term has not the same meaning here as when applied to Ordovician strata in Sweden or Norway. Likewise C_1 is called the "Echinosphaerites" limestone, though Echinosphaerites is equally common at some localities in C_2, C_3 and the lower part of D_1.

Description of Formations.

Cambrian.

Esthonia formation. A_1 and part of A_2 (Blauer Thon and lower part of Ungulitensand) of Schmidt. Lower Cambrian.

Since it has been so well described by Schmidt (42), Mickwitz (33), and Holm (20), the writer paid comparatively little attention to the study of the Cambrian, but examined the exposures at Reval, Port

Kunda, Ontika, Peuthof, and Papowka, and studied especially the contact of the Cambrian and Ordovician near Baltishport and at Narwa. The best section seen was at the cliff Peuthof, which is north of the station Waiwara, a few miles west of Narwa. Alternating strata of light colored sandstone and blue clay-shale were there well exposed, but the strata can be studied more in detail at Port Kunda, where Mickwitz found specimens of *Schmidtiellus mickwitzi*, the mesonacid which first afforded definite proof of the Lower Cambrian age of these strata.

It has been repeatedly stated that the "Blue Clay" underlies the sandstone of the Cambrian, but I did not find this to be the case. Everywhere the highest layer of the Cambrian appeared to be a hard, usually almost white, sandstone. The upper bed, where its thickness could be seen, was usually not over fifteen to twenty-five feet thick, and beneath it was a bed of blue clay-shale of variable thickness. Below this again one finds sandstone and alternations of shale and sandstone continue to the base of the cliff, and, according to borings in Reval and Petrograd, such alternations continue downward about 600 feet to the gneiss. The fossils have been found in the upper zones, within fifty feet of the top of the formation, and there is no reason to believe that strata of any age other than Lower Cambrian are present in this formation. The "Blue Clay" of the Lower Cambrian has received considerable notoriety, as it has often been reported as a soft, unconsolidated blue clay which could not be distinguished from clay of glacial age. Masses of this sort were seen at two places, at Papowka south of Petrograd, and on the shore at Ontika. In neither case was the clay actually in position either under or between layers of sandstone, but it lay in such a position that it could be readily conceived that it was Cambrian clay which had worked out from a layer nearby. In both cases it was very full of water, and it is probable that it represented a portion of a stratum of shale which had been worked up by the action of frost, water, and a creeping movement, until all traces of the original stratification had been destroyed. Where mined from the layers for the cement plant at Port Kunda, the clay is well stratified, and hard. It is, however, very fine grained, soapy to the touch, and a very fine plastic clay. The quickness with which it loses its stratification on weathering is probably due to its fine grain and the readiness with which it takes up water, rather than to the fact that it has never been consolidated.

In discussing the finds of "Olenellus" at Kunda and near Reval by Mickwitz, Marcou (31) proposed for the Lower Cambrian strata as developed at these two localities the geographic name Esthonian, which may now with propriety be applied to all the Lower Cambrian strata in the whole district. Of the two localities first mentioned, Kunda, and Strietsberg near Reval, the former presents the better outcrop, and it may be taken as the type-section of the Esthonian.

Ordovician.

Packerort formation. Upper part of A_2, and A_3 (upper part of Ungulitensand and the Dictyonemaschiefer or Alunschiefer), of Schmidt. (Plate **7**).

The most instructive section of the formation to which this new name is given is to be found at the base of the perpendicular 80-foot-high-cliff upon which is built the light-house Packerort at the end of the peninsula north of Baltishport. At the base of the cliff one sees, partly in the water, eight feet of hard, almost white, coarse-grained sandstone, representing the top of the Esthonia formation. Resting upon this is a bed of conglomerate, the matrix of which is an iron-stained sandstone, and which contains well-rounded boulders ranging from a few inches up to four feet in the greatest diameter. The boulders are all of sandstone, with some small pebbles of quartz, and are very numerous, making up the whole of that part of the formation which rests upon the Cambrian. This conglomeratic layer is very irregular, and only two or three feet thick. It is succeeded by alternations of thin layers of sandstone and a very dark gray, friable, soft shale. Above this comes a very irregular layer, five to ten feet thick, of cross-bedded, coarse-grained sandstone with great numbers of *Obolus apollinis* in the upper part. Then follows a band of thin-bedded dark gray shale like that below, but in certain layers, containing great numbers of graptolites, principally *Dictyonema flabelliforme*. As these strata rest upon the undulating surface of the sandstone below they have a variable thickness, from thirteen to eighteen feet.

The conglomerate at the base of the formation was seen also along the river north of the railroad bridge at Narwa. The pebbles at that locality were all rather small, the largest seen being ten inches in diameter. The interbedding of the shale and sandstone was seen also at Asserien, and although the sandstone and shale of this formation are usually in distinct bands, these sections show that the two are intimately associated and belong to the same time. The conglomerate and sandstone indicate the shore phases of the earliest Ordovician transgression; the shale with the graptolites a later shallow water phase. The still later deeper water limestone phase, with the Ceratopyge fauna, seems never to have reached this region.

Mickwitz fully recognized the physical evidences of an erosion period between the Lower Cambrian and the time of deposition of the Obolus sandstone, and in the preface to his paper on Obolus (33), he gives some excellent detailed sections of the Obolus sandstone. He recognized the basal conglomerate at Packerort, which he illustrated by a diagram, and he gave also a diagrammatic representation of the strongly eroded top of the Lower Cambrian sandstone at Jamburg on the bank of the Luga, east of Narwa. At this latter locality, the Obolus sandstone, with conglomerate, fills hollows and cracks in the Lower Cambrian sandstone.

The dark shale at the top of the formation is thicker at Packerort than in any other section, and, as has been noted already by Schmidt, it thins to the eastward, until it is entirely absent at Narwa. Still further east it comes in again and is seen far eastward, being four and one half feet thick at Papowka and one foot on the Lawa at Wassilkowa. Bassler cites the variable thickness of the Dictyonema shale as evidence of erosion before the time of deposition of the overlying "Glauconite sandstone." The evidence on this point does not seem entirely clear, and the presence at Narwa of only four inches of "Glauconite sand" at the point where all the shale is missing does not favor that interpretation, as one would expect the greatest amount of sand in the deepest erosion hollows. Moreover, the glauconite sand is thickest where the shale is thickest, and suggests the alternative explanation, partly borne out by its fauna, that the "Glauconite sandstone" may really belong to the Packerort formation, representing the deposits of the third and emergent phase of the cycle. It should be noted that the Dictyonema shale is usually unfossiliferous, fossils being common only along the western portion of its outcrop, the most western locality being on the island Odensholm where they are found in loose pieces cast up on the shore and the most eastern so far reported being on the Isenhof stream between Asserien and Ontika.[1]

[1] Eichwald (17), however, reports Dictyonema from as far east as Zarskoe Selo, south of Petrograd, and also at Narwa, where there is no Dictyonema shale. According to Schmidt (47), Dictyonemas have been found in lenses of limestone at the latter locality, and this was probably the source of the ones reported by Eichwald. This of course suggests that the Glauconite sand at Narwa may not be a representative of the real Glauconite sand as developed at other localities, but a residium from the Dictyonema shale. Lamansky (29, p. 197) states that graptolites have also been found in the Lower Linsenschicht at Narwa, and that they were sent to Dr. Holm for study, but I have found nothing more in the literature about them. Lamansky thought that they would prove to be the same as those found by Holm in Oeland (Tetragraptus fauna).

At Packerort the most fossiliferous layers are in the upper part of the shale, and it might be inferred from this that in the eastern region the upper layers had been removed by erosion, but it is equally possible that they were never deposited there.

The characteristic fossils of the Packerort formation are the various species of Obolus, chiefly *O. apollinis*, in the sandstone, and *Dictyonema flabelliforme* in the shale. Species of other genera of inarticulate brachiopods are found in the sandstone, and the shale has furnished several species of graptolites which have not yet been satisfactorily identified. If Schmidt's (44, p. 16) figures are to be trusted there may be a Didymograptus in this fauna.

The Obolus or Unguliten sandstone, has, like the Lower Cambrian clay of the same region, often been cited as an example of a formation which has never been consolidated. At nearly all exposures it is a friable sandstone which crumbles readily under the hammer, but in certain places it has considerable hardness, and one receives the impression that the present condition is due to the removal of the cement through leaching. The surface water enters the sandstone through joints in the overlying limestone, and being checked in its further downward passage by the Cambrian clays, naturally moves through the sandy beds.

Walchow formation. B_I and B_{II} (Glauconitsand and the Glauconitkalk) of Schmidt; B_I, $B_{II\alpha}$, $B_{II\beta}$, $B_{II\gamma}$ and $B_{III\alpha}$ of Lamansky.

While the Packerort formation is best developed at the extreme western end of the Ordovician outcrop, the succeeding formation finds its best expression in the east. This, however, is not due to the fact that the Walchow formation was deposited in a sea invading from the east, for the opposite seems to be the case, but because the upper layers have been eroded away at the west, as has already been shown by Lamansky (29). The lower members of the formation, the "Glauconitsand" and the "Glauconitkalk" are better developed in the west than in the east, and the deposits of the same age as the Glauconitkalk are still thicker in Sweden.

On the Walchow and on the Lawa at Wassilkowa this formation has five bands easily distinguished on lithological grounds, each with its own faunal characteristics. The measurements given here are those of the section on the Lawa which presents a more satisfactory natural section than any seen on the Walchow. (Plate **4**).

The lowest bed is a soft, easily disintegrated green sandstone, six feet in thickness. Upon it rests two or three layers of limestone, making a total thickness of six feet, which usually form a bold projection from the cliff, being preceded and followed by softer strata.

These layers are often vividly colored, being generally red or purple with patches and spots of green and yellow, and usually contain quantities of rather large green grains of glauconite. The characteristic fossil is *Megalaspis planilimbata.* Above these layers comes a band, thirteen feet in thickness, of thin-bedded, shaly limestone and shale in which *Asaphus bröggeri* and *Onchometopus volborthi* are found. These strata weather to a soft gray mass, and above them are harder layers of limestone with less shale, making the fourth division, eleven feet in thickness. This also is a blue-gray limestone, and contains *Asaphus lepidurus* and *Megalaspis gibba* in numbers. At the top of the formation is another thinner-bedded, softer, gray and green limestone, characterized by a great abundance of *Asaphus expansus*, and containing also *A. lamanskii*, and *Nileus armadillo*, this limestone being about ten feet thick. This makes the total thickness of the formation on the Walchow and Lawa about forty-six feet.

When followed westward this formation becomes thinner and usually at the expense of the upper members, though the green sand may thin to practical disappearance. Thus, on the Papowka, the green sand is only one foot thick, the *Megalaspis planilimbata* or lowest limestone bed is seven feet thick, and is followed by twelve feet of shaly limestone, the greater portion of which contains the *Onchometopus volborthi* fauna, while at the top, *Asaphus lepidurus* and *Megalaspis gibba* are found. The layers with *Asaphus expansus* are gone entirely. Further west, the shale almost entirely disappears from this part of the section, though there is usually a thin shaly layer or a shaly parting. The limestone of the section becomes very thin, but the three faunas, *M. planilimbata*, *Onchometopus volborthi*, and *Asaphus lepidurus*, persist as far west as Reval, though further west the *Asaphus lepidurus* fauna is lost, and of the zone with *Asaphus bröggeri* and *Onchometopus volborthi* only a thin remnant remains in the section at Packerort. At this latter locality the green sand has the greatest thickness known, eleven feet, followed by two and a half feet of hard green limestone with large grains of glauconite and many trilobites, among them *Megalaspis planilimbata*, then one foot three inches of thin-bedded limestone and shale, this containing *Asaphus bröggeri*. The limestone of the formation is therefore only three feet and nine inches in thickness, the two younger faunas are absent entirely, and the strata containing the others are very thin. Besides the absence of the younger faunas there is other evidence which indicates that erosion has taken place since the deposition of the upper strata of this formation. In the section at Packerort, the thin-bedded limestone is followed by a conglomerate in which there are large numbers of pebbles of green and gray limestone and pieces of shale; and at Catherine Park, Reval, the green "Glauconitkalk" is likewise followed by a six inch layer of conglomerate in which there are pebbles of limestone full of glauconite. This unconformity is not newly discovered, but was distinctly foreshadowed in Schmidt's papers, and was definitely worked out by Lamansky, who, however, placed the layers containing *Asaphus expansus* in the overlying formation instead of with the older strata, as the evidence seems to require. (Plate **2**).

The doubtful member of this formation is the green sand. It is placed here, because there is an undoubted break in the sedimentary record between the Dictyonema shale and the *M. planilimbata* limestone. In Norway and Sweden one finds between these two formations the Ceratopyge limestone, with a fauna which, though it occupies no great thickness of strata in Scandinavia, really endured for a very long period of time. During this interval no deposition was taking place in the region in Russia here discussed, and, apparently, neither was there any great erosion, the district standing nearly at sea-level. During some part of this time the green sand seems to have accumulated, perhaps as a beach sand, at least at first, but probably reworked as a whole or in part by the invasion of the sea in which were deposited the Walchow sediments. It differs from an ordinary beach sand not only in its green color, but in the presence of much fine clay. It usually shows neither stratification nor cross-bedding. The fauna is a scanty one. In the west, on the Baltishport peninsula and near Reval, a few specimens of *Obolus lingulaeformis* Mickwitz, a Lingula, a Siphonotreta and conodonts have been found. At Papowka, Lamansky has referred to the "Glaukonitsand" a sandy part of the limestone, and has obtained from it a considerable fauna which he considers to be distinct from the regular *M. planilimbata* fauna and allied to the Ceratopyge fauna of Scandinavia. This fauna is however, too closely allied to the *M. planilimbata* fauna to indicate the presence of either a Ceratopyge or Lower Didymograptus fauna, and the strata containing it would seem to go naturally with the limestone rather than with the sandstone of the section.

So far as I have seen it, the fauna of the green sand seems to be allied with that of the Ungulite sandstone below, rather than with the limestone above. The sand and clay content of the bed may easily have been derived from the denudation of the underlying Packerort formation, which was undoubtedly uplifted and subjected to erosion at some localities, even though we can not now point definitely to the particular places, and, such being the case, it seems more probable that the sand belongs to the later and not the earlier sedimentation.

In the east, on the Lawa, Walchow, and other rivers of that district, the limestone of the Walchow formation is rather soft, and disintegrates very readily on exposure, so that great numbers of very beautifully preserved fossils may be obtained, especially in the extensive quarries on both sides of the Walchow above Old Ladoga.

The lowest limestone has a decidedly green color, due to the presence of a considerable quantity of glauconite. The glauconite is in small grains about .5 mm. in diameter, and makes a considerable part of the limestone. In Esthonia the corresponding bed is much harder, is a deeper green in color and contains more and larger grains of glauconite, up to 2 mm. in diameter.

All of the limestone in the formation on examination in thin section proves to be made up almost entirely of fragments of fossils, largely trilobites, but also ostracods, bryozoans, and brachiopods. All these are in small pieces, sometimes 2 mm. long, but generally much less. The cement consists of exceedingly small grains of crystalline calcite. Stray grains of glauconite are seen in most of the slides from all horizons in the formation. The red and brown colors of some of the limestone prove to be due to a stain and grains of limonite surrounding the crystals of the matrix and filling the zoecia of the bryozoans. The limonite halo around the grains of glauconite suggest that the source of the iron compound may possibly be found in the decomposition of that mineral. (Plate 5).

In a slide from Putilowa especially, very few of the glauconite grains are unaltered, but almost all show a border of limonite, and the grains contain much of a dark alteration product along cracks.

The glauconite from the glauconite sand and limestone has been analyzed by Kupffer (27), some of whose analyses are quoted below.

	1	2	3	4
SiO_2	51.93	51.24	50.91	52.38
Al_2O_3	9.20	12.22	9.81	10.53
Fe_2O_3	15.31	13.44	16.54	13.77
FeO	4.73	3.06	4.80	4.36
MgO	3.79	3.93	3.62	4.96
CaO	.30	.10	.30	.08
KO	8.02	7.50	8.09	8.00
NaO	.20	.31	.14	.04
HO	5.52	8.20	6.48	5.88
Quartz	.40			
	99.40	100.00	100.69	100.00

The analysis given in column 1 was from the glauconite sand at Karya-Oro near Ontika, Esthonia, and 2 from the glauconite limestone at the same place; 3 was from the glauconite limestone, and 4 from the glauconite sand, at Baltishport.

For comparison, one may quote the following, the first two from Clarke's Data of geochemistry, p. 494, and the other three from an abstract of a paper by Glinka. (Zeitschr. kryst. u. min., 1898, **30**, p. 390).

	1	2	3	4	5
SiO_2	51.56	53.61	48.95	49.53	52.96
Al_2O_3	6.62	9.56	7.66	5.84	12.76
Fe_2O_3	15.16	21.46	23.43	20.06	13.56
FeO	8.33	1.58	1.32	5.95	2.34
MgO	.95	2.87	2.97	2.92	4.11
CaO	.62	1.39	.57	.56	....
Na_2O	1.84	.42	.98	.46	.47
H_2O	10.32	5.96	4.93	4.91	4.91
K_2O	4.15	3.49	9.54	9.31	8.69
MnO	.....	trace	....	....	....
	99.55	100.34	100.35	99.54	99.80

The glauconite in column 1 is from a greensand marl, Hanover Co., Virginia; 2 is the mean of four analyses of deep-sea deposits from the Challenger Report; 3 is a glauconite from the Cretaceous sandstone at Padi, Government of Saratow, Russia; 4 is from an Eocene sandstone in the Urals; 5 from the Glauconite limestone at Udriass, Esthonia.

It will be noted that the Russian Ordovician glauconite contains less iron, more alumina, much more magnesia, and more potash than the other glauconites listed.

Kunda formation. B_{III} (Vaginatenkalk) of Schmidt; $B_{III\beta}$ and $B_{III\gamma}$ of Lamansky.

This well-known formation may be seen throughout the whole extent of the Ordovician from the Sjass to the Island Rogo, off Baltishport, but is best exposed in Esthonia. I have selected Kunda as the type-section because it is there well exposed and richly fossiliferous. A drain recently dug by the Cement Company at the extensive quarries about three miles south of Port Kunda on their private railroad exhibits a complete section of the formation, which is here fifteen feet thick. A large quarry, opened during the summer of 1914 will, if completed as planned, also furnish a complete section through the limestone. This formation is quite thick in the eastern exposure on the Walchow but is very poorly exposed, only the basal portion being cut by the extensive quarries, and the greater part being seen only at places along the river bank just below Dubowiki.

At the base of the formation one finds the so-called "Lower Linsenschicht," a rather soft clayey limestone six to twelve inches in thickness, full of small flattened grains of about the size, shape, and color of small Leperditias, with which Schmidt first confused them. These small "lentils" have a concretionary form and have been shown on chemical analysis by Kupffer (27), to consist of clay containing iron oxides and calcium phosphate.

The layer containing these linsen does not seem to have been formed under abnormal chemical conditions, for it is fossiliferous, often highly so, being in fact noted as the best stratum for *Pliomera fischeri* and *Lycophoria nucella*, and the fossils are of full size and show no abnormalities. It is probable that the "Linsenschicht" really represents a basal conglomerate for the Vaginatenkalk, for in places, as at Reval and Packerort, there is a real conglomerate which replaces the "Lower Linsenschicht."

East from Reval this conglomerate was not seen, and west from that city there is no "Lower Linsenschicht," but both the conglomerate and the "Lower Linsenschicht" represent the basal bed of the formation.

The "linsen" of the Linsenschicht are almost opaque in the thinnest sections which can be obtained of these soft rocks, but show a definite concentric structure.

An analysis of some of them from Ontika by Kupffer is as follows:

SiO_2	5.93
Al_2O_3	3.95
Fe_2O_3	69.92
Mn_2O_3	.26
MgO	1.21
CaO	.46
P_2O_5	1.99
HO	12.42
Organic	.68
Residue	3.09
	99.91

This analysis may be compared with those of the oölitic hematite ore of the Clinton of New York, listed by Newland and Hartnagel (Bull. 123, N. Y. state mus., 1908, p. 62).

	1	2	3	4	5
Fe_2O_3	69.17	42.97	79.98	63.00	71.82
SiO_2	11.57	29.72	9.98	12.63	11.34
Al_2O_3	3.92	4.13	2.4	5.45	3.91
MnO	.19	.37	tr.	.15	1.63
CaO	5.8	8.57	1.54	6.2	3.97
MgO	2.27	1.96	.3	2.77	2.21
S	.28	.837		.23	
P_2O_5	1.726	1.534	1.239	1.5	2.096

Comparing these analyses, it will be noted that the "linsen" have about the same iron content as some of the Clinton oölites, and about the same amount of clay, manganese, and phosphates, but less silica, lime, and magnesia. The high silica content of the Clinton ore is due to the presence of nuclei of sand in the spherules, whereas the nuclei of the linsen, when such can be observed at all, seem to be calcitic fragments of fossils.

The linsen have much the same size and shape as the spherules in the oölitic Clinton ore, most of them being from .5 to 1 mm. in diameter, and somewhat flattened or lentil shaped. This flattening, in the case of the Clinton oölites, has been ascribed to pressure, but in the case of the linsen it seems to be the original form, for, while these discs often lie parallel to the bedding, very large numbers of them do not, but are imbedded at all angles.

The mode of occurrence of these linsen has some bearing upon the rival theories of the origin of the oölitic sedimentary hematite ores. The view put forward by Shaler was that they were replacements of original limestone effected by the circulation of ground water, while C. H. Smyth, Jr., considers these ores to be original sedimentary deposits. The Russian occurrences are explainable only by Professor Smyth's views, since: —

First; the linsen occur in a limestone which is not otherwise oölitic.

Second; the linsen occupy definite layers which can be traced laterally some 300 miles through a series of gentle undulations, always maintaining a definite horizon, as shown by evidence of fossils, and without any relation to the present water table.

Third; the lower linsenschicht passes laterally into a true conglomerate showing that it was formed at or near the shore, and at a time immediately subsequent to a period of erosion.

The Kunda formation has a somewhat irregular thickness, being thickest in the east and very thin at the west. On the Walchow it is thirty-two feet according to Lamansky, at Papowka it is thirty-four feet with the top not seen, at Ontika eighteen and one half feet, at Asserien fourteen and two thirds feet, at Kunda fifteen feet, at Reval four feet, and three and one half feet at Packerort. The abundant fauna at Reval is practically the same as that at Kunda, but as the fauna seemed to be the same all through the section at Kunda, this in itself would not indicate whether the thinness at Reval was due to erosion at the top of the formation or to a smaller original deposition.

Schmidt states that west of Reval the Orthoceras limestone passes into a sandstone, but I myself saw no evidence of this, either at Baltishport or on the Island Rogo. At these localities the formation consists of a rather thick-bedded hard limestone without many fossils, and at the base is a conglomerate made up of pebbles of green glauconitic limestone and irregular pieces of dark shale, these latter proving on analysis by Kupffer to contain, in some cases, a large percentage of phosphoric acid.

The fauna of the Kunda formation is dominated by Mollusca, mostly cephalopods and gastropods. Pelecypods are rare, making here their first appearance in the Russian section. Typical fossils are *Vaginoceras vaginatum*, *V. commune*, *Maclurites helix*, *Estonioceras lamellosum*, *Asaphus raniceps*, *Pliomera fischeri*, *Lycophoria nucella*, and *Pterygometopus sclerops*.

WIERLAND GROUP. C1, 2 and 3, and part of D_1 (Echinosphaerites limestone, Kuckers schicht, Itfer schicht, and basal portion of the Jewe schicht), of Schmidt.

As already noted, Schmidt gave geographic names to all the strata above the "Glint," but these names are of very unequal value, some of them designating true formations, and others indicating merely the quarry at which a certain fauna or type of strata was seen. The faunas of all three of the formations named above are very closely knit together by the presence of *Echinosphaerites aurantium* and species of Chasmops. The name Wierland which I have applied to the group is that of the district in which most of the localities for Kuckers and Itfer are located, and in which the lower divisions are well developed. The lower members are also given geographic names to correspond to the two upper members named by Schmidt. There is really a greater faunal change between the Reval and Dubowiki members than between any other two in the group.

Dubowiki formation. C_{α} (Upper Linsenschicht and lower part of the Echinosphaerites limestone), of Schmidt.

This formation, like the Kunda limestone is best exposed at the east, where it reaches its best development on the Walchow River at St. Michael Archangel, opposite Dubowiki, just above the steamer landing and below the railroad bridge. At this locality the base of the formation is not seen, but fourteen feet of soft calcareous mudstone are exposed, the base twenty-three and one half feet above water level in the river. This outcrop is capped by twelve feet of the harder dolomitic limestone of the Reval formation. Schmidt and Lamansky state that the upper part of B_{III} (the Kunda formation) is to be seen in the basal parts of the quarries at St. Michael Archangel, but I was not able to find it, and so did not see the contact between the two formations here. The upper part of the Kunda is, however, exposed along the river bank about a mile below the steamboat landing and with the prevailing low dip should still be above the water-level at St. Michael Archangel. The thickness of the Dubowiki at this locality is therefore uncertain. It can not be more than thirty-seven feet or less than fourteen feet in thickness, and is probably twenty-five to thirty feet. as Dubowiki fossils, which seemed to be in place, were found within ten feet of the water's edge.

Schmidt and Lamansky agree that there is no "Linsenschicht" at the boundary between B_{III} and C_1, at this locality. Following the Dubowiki westward it is present at various sections, but always thinner than at the typical locality. It is well exposed in the cement quarry and on the railroad south of Asserien, where it is fifteen and one half feet in thickness. It is here a hard compact limestone, unlike the soft marly beds at Dubowiki; and at this locality, as well as at Ontika and all the other localities in Esthonia the "Upper Linsenschicht" is present at the base of the formation. This linsenschicht is not a definite, rather thin band, like the Lower Linsenschicht, but the linsen are smaller, less abundant, and scattered through a thickness of six or seven feet. Continuing westward, the Dubowiki formation thins out entirely, so that at Reval the upper Linsenschicht is reduced to a thickness of one foot and at Baltishport to ten inches, and it is at the base of the Reval formation instead of the Dubowiki. The Upper Linsenschicht is therefore a tangential formation and represents the invading base of the Wierland group.

The fauna of the Dubowiki retains some survivors of previous faunas, though very few species are common to this formation and those below. This formation is particularly marked by the introduction of Echinosphaerites and Chasmops, and the acme of the variation of the genus Asaphus. Echinosphaerites is not found in the Linsenschicht at the base of the formation, though it does occur with linsen a few feet above the base at some localities (Ontika and Asserien).

The soft limestone from St. Michael Archangel, on the Walchow, weathers to a nearly white flour which, when wet, forms a very sticky mud. A thin section shows that this rock is made up almost entirely of very small fragments of fossils, few of which reach 1 mm. in length and none have more than one fourth that thickness. The most abundant fragments are of some organism with minute tubules, possibly a Solenopora. Bryozoa, Ostracoda, and trilobites seem to furnish a large part of the material. The fragments are much more finely comminuted than in the limestone of the Walchow.

Characteristic fossils are: — *Echinosphaerites aurantium, Clitambonites adscendens, Porambonites aequirostris, Chasmops nasuta, Ceraurus exsul, Illaenus tauricornis, Asaphus cornutus,* and *A. kowalewski.*

Reval formation. $C_{1\beta}$ (upper part of Echinosphaerites limestone) of Schmidt.

Resting upon the Dubowiki at Dubowiki on the Walchow, and through the greater part of Esthonia, and upon the Upper Linsenschicht from Reval westward, is a hard, compact, sparingly fossiliferous limestone, frequently magnesian in character, to which the name Reval may be applied, as it is very extensively quarried at that locality. The thickness and lithological character of this formation are remarkably uniform all the way from Baltishport to Dubowiki and it is a favorite quarry rock wherever accessible. The beds vary in thickness from an inch to about a foot and afford both building and flagging stone. It is extensively used for both purposes in Reval, Narwa, and Petrograd. Certain of the layers are traversed by vertical tubes suggesting worm-burrows. The thickness varies from twenty-five to thirty-five feet. Fossils are not very common, and in many cases dolomitization has gone on to such a degree that the rock has a porous appearance and the fossils are represented by hollow molds.

The rock has about the same color and appearance as the Galena of Minnesota, and there does not seem to be much question but that the dolomitization has here taken place in beds originally composed mostly of limestone. In thin section the rock from Dubowiki shows irregularly intergrown areas of very small crystals of calcite with irregular boundaries, and areas in which the crystals are of dolomite, about twice the size of those in the areas of calcite, and with definite crystal form. This rock is not made up of fragments of fossils, like that of the calcareous formations below.

The leading fossil of this formation is *Christiania oblonga* (Pander). Some large cephalopods are found, and in the Government of Petrograd, *Cryptocrinites laevis* (Pander) is a characteristic fossil, and *Echinosphaerites aurantium* (Gyllenhahl) is occasionally found.

The Reval is the youngest formation which appears in the "Glint."

Kuckers formation. C_2, (Kuckerssche schicht or Brandschiefer) of Schmidt.

The Kuckers formation takes its name from the estate of Baron Toll, about five miles northeast of the railroad station Jewe; but the strata are very little exposed at that locality and collecting is now very poor. The same strata are reported by Schmidt to be exposed in a few natural sections along streams but the places were difficult of access and we saw the Kuckers only at the typical locality and at Reval. The formation occupies the low, level land at the top of the escarpment which faces the Gulf of Finland, and the numerous beautiful fossils which it has produced have come from ditches dug to drain this sort of land.

The base of this formation can be seen in the extensive quarries at Reval where the upper three or four feet are a bluish gray calcareous shale and thin-bedded shaly limestone containing numerous cystids, including *Echinosphaerites aurantium*, *Caryocystites balticus*, and *C. aranea*.

In the trench at Kuckers the strata consist of gray and reddish earthy limestone and soft reddish shale known from its combustibility as the "Brandshiefer." Schmidt has listed localities in this formation all the way from the village of Djatlizy south of Gostilizy and west of Petrograd to the point where it goes beneath the waters of the Gulf of Finland southwest of Baltishport. Its large fauna is rather easily recognized. *Chasmops odini*, *Ceraurus spinulosus*, *Porambonites teretior*, *Plectambonites sericeus*, *Oxoplecia dorsata*, *Echinosphaerites aurantium*, and *Platystrophia lynx* were the more common species seen by the writer. Of these, the *Oxoplecia dorsata* is most valuable as a cosmopolitan form, but, in Russia, confined apparently, to this horizon.

Schmidt estimated the thickness of the Kuckers at from thirty to fifty feet.

Itfer formation. C_3 (Itfersche schicht) of Schmidt.

This member is named from an exposure on the estate of Baron Wrangel at Itfer, northeast of Wesenberg. This exposure, a small quarry, is now completely overgrown and nothing is to be seen. I was able to find the formation in another small, shallow, old quarry at Wannamois, and in a small ditch at Tolks. The strata here consist of thin-bedded (layers two to four inches thick) gray and almost white limestone, rough to the touch, full of silica, and with silicified fossils. The fossils included *Echinosphaerites aurantium*, which species we also found in the lower layers of strata assigned to the next formation, the Jewe, at the quarry south of the Guthof at Kuckers, and at Aluver, north of Wesenberg. As this species does not occur in the typical Jewe, I propose to extend the Itfer to include all the strata at the above localities which contain Echinosphaerites. These strata lack the shale of the Kuckers member and are lithologically unlike the Jewe, as they weather to a grayish white instead of a rusty yellow.

The geographical distribution of the Itfer is unknown. It is difficult to trace, as it has few fossils peculiar to it, and no very distinctive lithological characteristics. It has not been identified outside the vicinity of the typical locality, but Baron Toll called our attention to an outcrop of strata on his estate which were stratigraphically a few feet above the typical Kuckers in the "Graben," and which may prove to be Itfer. They consisted of a thin-bedded soft, earthy, gray limestone, and contained too few fossils to permit of positive identification of age.

Schmidt estimated the thickness of the Itfer at twenty to thirty feet.

Jewe formation. D_1 (Jewesche schicht, except for the basal portion), of Schmidt, but not including the Kegel and Wassalem.

The Jewe is a formation with distinct lithological characteristics, contains a well-marked and easily recognized fauna, and is well exposed along a line extending from Gatschina in the Government of Petrograd to the coast near Spitham in the northwestern corner of Esthonia.

At the type-locality, Jewe, in an abandoned quarry south of the railroad there is an exposure of about twelve feet of light gray to yellow magnesian limestone of earthy texture. Some layers are more shaly than others and weathering brings this out strongly. Still higher strata of the same formation are to be seen a mile to the southwest on the Gut Eichenheim, where, in similar strata, fossils are somewhat more plentiful.

A much better exposure of the Jewe is that at Aluver on the railroad to Kunda, three miles northeast of Wesenberg. Here about twenty-five feet of the Jewe are shown in a quarry, with the upper part of the Itfer, full of Echinosphaerites, exposed at the lower part. The rock is a fairly compact bluish limestone with earthy texture; on weathering it becomes a mass of rusty yellow fragments. Fossils are very plentiful in the upper part of the quarry. The Jewe covers a large area north of Wesenberg and small quarries and ditches furnish many exposures. I saw the Jewe further west beyond Nemme, about seven miles southwest of Reval and at St. Mathias, five miles south of Baltishport. At both these localities the fossils and lithology were the same as at Jewe itself and the formation is throughout its extent a very distinctive one. The most common and characteristic fossils are: — *Platystrophia lynx* (very robust variety), *Clitambonites schmidti*, *Hemicosmites extraneus*, and *Poramborites ventricosus*. Equally characteristic are the peculiar conical bodies figured by Schmidt (44, p. 331). These appear to be of organic origin, but their exact nature is not known.

Kegel formation. D_2 and D_3 (the Kegel, Wassalem and, west of Reval, the "Wesenberg") of Schmidt.

At the typical locality, at Kegel, southwest of Reval, about eight feet of strata are exposed in two quarries about one and one half miles west of the station. The strata here are limestone without shale, in layers two to six inches thick. When fresh the limestone is blue and fine grained, but weathers to a yellow shaly mass. The fossils weather more rapidly than the matrix and the rock is left full of holes. The most abundant fossil is *Cyclocrinites spasskii*, which occurs in immense numbers. *Clitambonites anomalus* and *Asaphus kegelensis* are also quite common. The country south of Kegel is very flat and the rock everywhere near the surface. Following the railroad or highway southwest from Kegel station, the Kegel beds with their characteristic fossils are seen in ditches and shallow quarries till one comes to a broad low ridge which is made up of a very different rock, to which the name Wassalem has been given. At the large quarries in Wassalem, the strata are light gray to white, very coarse-grained massive limestone, the lower ten feet with feebly developed partings, the upper three feet very irregularly bedded and containing some shaly lenses. The lower part is quarried in large blocks, up to three feet in thickness, for use as a marble. In this portion there are few fossils, other than joints of the columns and plates of Hemicosmites. Weathered pieces show that the rock is practically made up of these. The upper three feet contain lenticular and cross-bedded strata and lenses of fine-grained buff limestone with numerous specimens of Illaenus. Fossils may be found in this upper portion, especially in pockets where the limestone has decomposed, leaving a mass of yellow, calcareous earth. The most common fossils are bryozoans and Hemicosmites. The

Wassalem thus shows at its type locality many of the characteristics of a reef. The outcrop of the Wassalem has a width of about two miles and south of it one finds blue and buff, very fine-grained dense limestone, somewhat purer than that at Kegel, but with the same fossils, *Cyclocrinites spasskii* (or *C. roemeri*, as Stolley calls it) being very abundant. This limestone appears to belong to the Kegel, though it has previously been called Wesenberg. The reasons for this belief are given on page 202. The Bryozoa described by Bassler as coming from the Wassalem were very probably derived from a lense of the fine-grained buff limestone associated with the reef, for their appearance and the lithology of their matrix is entirely unlike that of the typical Wassalem. (Plate 6).

Wesenberg formation. E (Wesenberger schicht, *partim*), of Schmidt. The strata of this formation are well shown in three or four shallow quarries about one and one half miles southeast of the town from which it derives its name. The limestone is a very fine-grained, dense, blue to yellowish buff rock, so fine grained as to have received the name of "lithographic stone." It is usually in layers three to five inches in thickness, the layers separated by thin shaly partings. The good fossils adhere to the limestone and stand out in relief when the shale is washed away. The deepest quarry shows a face of sixteen feet, the lower eight feet being compact light blue limestone and the upper eight feet somewhat less compact and more magnesian limestone which becomes yellowish on weathering. Lithologically these strata differ from the rocks of the Kegel at Kegel in being less earthy, more compact, and in containing definite partings of shale. Fossils are exceedingly abundant in these quarries, the most conspicuously common being *Amphilichas holmi*, *Homolichas eichwaldi*, *Chasmops wesenbergensis*, and *Encrinurus seebachi*.

The Baltic railroad runs in a southwesterly direction from Wesenberg to Taps and thus traverses the outcrop of the Wesenberg diagonally. Between the two stations there are several small cuttings, one of them, about two miles east of Taps, being in strata very near the top of the formation. A tiny quarry, a few rods south of the railroad and near the stream just east of Taps shows strata even higher in the formation. In both localities the rock is a hard fine-grained yellowish to buff limestone, without shale, and fossils were exceedingly scarce. In the small quarry I obtained *Clitambonites wesenbergensis*, a *Discoceras*, and *Chasmops wesenbergensis*, fossils which are characteristic of the Wesenberg at the type-locality. A half mile south of these outcrops one finds the Lyckholm, with typical fauna.

The Wesenberg was believed by Schmidt to be a thin formation, the thickness being estimated by him at not more than thirty feet. From the width of the outcrop in the vicinity of Wesenberg, one would expect a somewhat greater thickness.

Distribution of the Kegel and Wesenberg formations.

According to Schmidt the outcrops of the Kegel and Wesenberg strata form parallel bands extending from the western part of the Government of Petrograd to the western border of Esthonia. In the eastern part of this belt the Wesenberg is said to overlie the Kegel proper, while in the western area the Wassalem intervenes between the Kegel and Wesenberg. I regret to say that I have not been able to trace these formations in the field as I should like to, but from what I have seen in the course of traverses in the neighborhood of Wesenberg and Taps, and between Baltishport and Hapsal, and the débris on the northern end of the Island of Dago, I very much doubt whether these formations do outcrop as parallel belts. The distribution of the Kegel is given by Schmidt in detail, as follows: — The most easterly outcrop is at Poll (a short distance east of Wesenberg) where the Kegel is said to outcrop in the ravine and the Wesenberg on the bank above; then north of Wesenberg, at New Sommerhusen, west of Taps on the railroad between Kedder and Rasick, at Penningby, Nappel, Jelgimäggi (south of Reval) Friedrichshof, Kegel, Habbinem, and Kreuz.

I did not see the locality at Poll, but visited the old quarry at New Sommerhusen, where the lithology and fossils are both typical of the Jewe, and not at all Kegel. The locality "north of Wesenberg" is probably an outcrop on the road to Haljal, and about three miles north of Wesenberg. Here, where the road mounts a slight terrace, is an exposure of nine feet of bluish and yellowish compact limestone containing many fossils, among which were *Amphilichas holmi* and the large Porambonites so common in the quarries at Wesenberg, and which are believed to be characteristic of that formation. If the strike here is approximately east and west, as it is supposed to be, and as it actually is in most places, then the strata at this locality must be but a short distance above the top of the Jewe, which outcrops at Aluver and New Sommerhusen at approximately the same level. In a ditch at Welch, about five miles northwest of this outcrop, I obtained, through Herr von Dane, some specimens whose matrix reminded me of the Kegel, but which were not diagnostic species. North of Welch there are numerous outcrops of the Jewe. If the Kegel be indeed present in the neighborhood of Wesenberg, it is either very thin or else does not carry the fauna of the Kegel at Kegel.

The next locality mentioned by Schmidt, that between Kedder and Rasick, is forty miles west of Wesenberg, and less than thirty miles east of Kegel. I did not visit this locality myself and am unable to find any adequate faunal lists for it or for any of the other localities mentioned between it and Kegel. Owing to its proximity to the latter place, however, it is very probable that one finds here a real Kegel fauna.

Schmidt gives the following localities from east to west, for the Wesenberg: — from Polja, on the River Pljussa in the western part of the Government of Petrograd, then at Paggar, Pülse on the stream Isenhof, at Poll, Raggafer, Wesenberg and other outcrops on the railroad in that vicinity, at Körweküll north of Taps, at Wait south and a little east of Reval, then southwest of Reval at Forby, Munnalas and Paeküll, and as boulders on the Islands Oesel and Dago. Of these localities I have seen only Wesenberg and the localities on the railroad as far as Taps, and the loose boulders on Dago, but have also seen material from Munnalas. The fossils listed by Schmidt from Polja, Paggar, Püllsse, Poll, Raggafer, and Körweküll leave no doubt that these eastern localities belong to the Wesenberg. When one inspects the lists, usually very meager, from the more western localities, beginning with Wait, one finds however, a marked change. In these localities the common, and usually the only fossil, is *Cyclocrinites spasskii,* a typical Kegel fossil, but one so rare at Wesenberg that I was unable to find it, though Schmidt has listed it from that locality.

On the shore at Kertel, on the northern side of the Island Dago, numerous angular blocks of limestone are found which are not seen in place, but which are evidently derived from a ledge not far below water-level. The blocks contain great numbers of *Cyclocrinites spasskii* and lesser numbers of other typical Kegel fossils. At the new factory at Hohenholm, west of Kertel, this same limestone was seen in a trench immediately in contact with the Lyckholm.

The fauna of the Kegel has never been carefully listed, the best enumeration being that given by Schmidt (44, p. 34). This one is, however, subject to considerable revision, and contains fossils found in both the Jewe and the Wesenberg. In both the Kegel and Wesenberg the trilobites are most important, because best known, and a study of their distribution throws considerable light on the present subject.

Of nine trilobites which are supposed to be restricted to the Wesenberg, four are found at Wesenberg only, one only at Wesenberg and Raggafer, and four are found in the western as well as the eastern localities. These are *Homolichas eichwaldi* and *Isotelus remigerum*, which occur at Forby as well as at the eastern localities, *Chasmops wesenbergensis* which is found at Wait and Forby, and loose on Dago, and *Pterygometopus nieszkowskii*, found at Wait and Munnalas.

There are eleven species of trilobites reported from the Kegel; six of which are common to the Jewe and Kegel and thus of no importance in this discussion; four, *Pterogometopus kegelensis*, *Chasmops brevispina*, *Basilicus kegelensis*, and *Illaenus linnarssoni*, are found only in the western localities; and a single one *Asaphus lepidus* var. *kegelensis*, is reported from both east and west. This last species has no particular value, for it is very like *Asaphus lepidus jewensis;* and it is reported by Schmidt not only from New Sommerhusen, which we know to be Jewe, but also from localities in the Government of Petrograd east of the limits which Schmidt himself set on the distribution of the Kegel. Of the six trilobites found in both the Kegel and Jewe, five are found in the Kegel in the typical region, while one, *Chasmops mutica*, is listed as a Kegel species only from its occurrence at New Sommerhusen. That there should be five species common to the lithologically unlike Jewe and Kegel, and no species common to the lithologically alike Kegel and Wesenberg strikes one as strange.

The results of the study are rather suggestive. Subtracting the one species reported from the "Kegel" at New Sommerhusen, there are nineteen species of trilobites reported from the Kegel and Wesenberg. Of these no one is reported as common to the two, while six of the species in the Kegel occur in the Jewe below. Of the four which may be considered strictly typical of the Kegel, not one is found at any locality of the Kegel east of the locality on the railroad near Kedder, forty miles west of Wesenberg. Of the nine trilobites in the Wesenberg, five are restricted to the typical region about Wesenberg and do not occur in the western region, and four are reported in both eastern and western localities, three of them at Forby, one at Wait, one at Munnalas, and one on Dago.

The most abundant fossil in the Kegel at Kegel itself is *Cyclocrinites spasskii*, using that term in its old, broad sense.[1] Following

[1] This usage is, I believe, fully justifiable. All of the five species described by Stolley (51), from Estbonia were found by him associated in the same blocks, so that, so far as their stratigraphic value is concerned, one specific name is as good as five. Most of Stolley's specimens seem to have come from loose boulders at localities south of the actual outcrop of strata containing these species.

the railroad or highway southwestward from Kegel, one continues to find Cyclocrinites as the common fossil until the coarse-grained, white limestone of the Wassalem is reached. After crossing the outcrop of this formation, the beds above are similar to those below, though with less shale, and still full of the Cyclocrinites.

Cyclocrinites seems to be confined very largely to the district west of the longitude of Reval. It is reported by Schmidt from the Jewe at Jewe and from the Wesenberg. At Jewe I succeeded in finding a few small specimens of *Coelosphaeridium cyclocrinophilum*, and this is probably the fossil which Schmidt had seen. At the quarries at Wesenberg I saw no Cyclocrinites, though I looked for it particularly, especially on my second visit, after I had collected many specimens at Kegel and in the loose blocks on Dago. It is therefore, I think, safe to assert that Cyclocrinites is a very rare fossil, if present at all, at Wesenberg.

Stolley reports no species from the quarries at Wesenberg, though he visited that locality, and also had access to the material collected by Schmidt (in Dorpat). Stolley (51) described or reported five species, *Cyclocrinites balticus*, *C. schmidti*, *C. mickwitzi*, *C. roemeri*, and *C. spasskii*, from Esthonia, all from the region southwest of Reval, and in the strata above the Wassalem.

At the United States National Museum I have seen specimens collected by Professor Schuchert at Wesenberg while in company with Akademiker Schmidt, and which are labeled *Cyclocrinites spasskii*. These specimens are none of them spherical, though some of them might be interpreted as fragments of spheres. Moreover, they do not show the surface structures of Cyclocrinites, and they do show that if they were originally spherical, they were not hollow spheres, but had a structure extending nearly to the center, as in Coelosphaeridium. I, myself, collected many similar specimens, as they are very common at Wesenberg. They are certainly not Cyclocrinites, and probably not Coelosphaeridium, but this identification, which was probably made by Professor Schmidt, explains the listing of Cyclocrinites from Wesenberg.

Summarizing what has been said on the preceding pages, it appears that: —

1st, the fauna of the strata above the Wassalem is more like that of the Kegel than that of the Wesenberg.

2nd, that the typical Wesenberg fauna is not found in the same region as the typical Kegel fauna, but that both the Wesenberg and the Kegel rest upon the Jewe and are followed by the Lyckholm.

The question suggests itself as to whether the Kegel may not be of the same age as the Wesenberg, instead of being older as has been supposed. On the basis of the faunas this must be at once answered in the negative, for there are only one or two of the long ranging species which are common to the Jewe and Wesenberg, while there are quite a number of species, particularly trilobites and brachiopods, common to the Jewe and Kegel.

The presence of a few of the Wesenberg trilobites at localities south of the outcrop of the Wassalem suggests that there may be a thin edge of the Wesenberg in that region, probably overlying the strata with the Cyclocrinites, but I did not have time to search for outcrops which might have shown such relations. It seems more probable, however, that these trilobites are not restricted to the Wesenberg horizon, but are found in the Kegel as well.

It seems very possible therefore, that the Lyckholm rests at the west on the Kegel and further east upon the Wesenberg, and there is undoubtedly an unconformity at the base of the Lyckholm, for there is at most, only a very small fraction of the normal thickness of the Wesenberg present south of Wassalem. The relations of the formations may be as represented on Plate 3.

THE LOWER AND MIDDLE ORDOVICIAN OF SWEDEN.

To make a direct correlation between the various subdivisions of the Ordovician in Russia and North America is impossible, the testimony of the few species common to the two areas being entirely outweighed by the general unlikeness of the faunas. It was a realization of this fact which caused a visit to Sweden and Norway after studying the Russian sections. I visited the rather complete and easily accessible section at Kinnekulle, and other sections in Västergötland at Hunneberg, Ekedalen, and Alleberg near Falköping. In Östergötland I collected at the large quarries at Borghamm and at the old quarry at Västanä, the Husbyfjol of the literature on trilobites, and visited a number of very poor localities in the vicinity of Motala. In Scania I had the very kind guidance and assistance of Professor Dr. J. C. Moberg, without whose help it would have been impossible for me to have understood the very imperfectly exposed sections on the Fågelsång and at Jerrestad. I was not able to visit Oeland on account of the war, neither did I see Dalecarlia, but Dr. Twenhofel made some collections for me from the district about Rättvik, on Lake Siljan. In Norway, I visited, under the guidance of Dr. Holtedahl, the Ordovician sections in the vicinity of Christiania and, partly with Dr. Holtedahl and partly with Professor Kiaer, some of the exposures of Stage 4 in the Ringrike district.

The description of the Palaeozoic strata of Sweden has been very ably summarized in English by Professor Moberg in his Historical-Stratigraphical Review of the Silurian of Sweden and a briefer summary of certain facts in regard to the lower beds of the Ordovician has been published by Fearnsides (59). I am indebted to these two papers, and to the original sources from which their facts were derived, for the greater part of what is here set forth in regard to the geology of Sweden. The greater part of the Ordovician of Norway is still inadequately known. The account here is derived chiefly from the works of Brögger (93–95), and Holtedahl (97). No account in English of this section, except that in Geikie's Geology, has, so far as I know, appeared.

The strata of Ordovician age in Sweden are found in isolated patches, usually of small area. These patches may be grouped in bands, having a roughly parallel NE–SW alignment.

The northern band, that in Jemtland and Lapland, has the greatest extent, running far north parallel to the mountains on the boundary between Norway and Sweden. These rocks are, however, except in the southern part, largely metamorphosed. The next band to the south of this has its best exposures in Dalecarlia, and there is a very small area in Gästrikland, especially on the little island of Limön near Gäfle. From the evidence of boulders and fossiliferous sand in cracks on the Åland islands, it would appear that this band may once have connected with the Esthonian strata. To the westward the strata of the Christiania district of Norway are in line with these patches.

The next band is in south-central Sweden, and includes the deposits in Nerike, Östergötland, and Västergötland, while the fourth band is at the extreme south and includes Scania and Oeland, while the Silurian of Gotland is in the same line. The strata are best exposed and least disturbed in Västergötland and Oeland. A brief description of the strata at some of the principal sections in each region follows. It is rather interesting to note that most of the principal lakes of Sweden are connected with these limestone patches. Thus we find Lake Storsjön in Jemtland, Siljan in Dalecarlia, Hjälmaren in Nerike, and the largest lakes, Vänern and Vättern in connection with the Palaeozoic deposits of Västergötland and Östergötland.

Jemtland.

The most recent general account of the Ordovician of Jemtland is that given by Wiman (87), to which account must be added certain facts obtained later by Moberg (75), Wiman, and Hadding (60).

The section of Palaeozoic rocks there is given by Wiman as follows:

Pentamerus kalk.
?
Chasmopskalk with Graptolithenschiefer.
Orthocerenkalk.
Underer Graptolithenschiefer.
Ceratopyge kalk?
Alunschiefer { Olenidenschiefer. / Paradoxidenschiefer.
Quarzit.

The so-called Ceratopyge limestone is conglomeratic at the base, containing fragments of the Olenus shales. Above it is a limestone with much glauconite, and at the top a somewhat pure limestone. This limestone contains some fossils, referred by Moberg definitely to the Ceratopyge fauna but which seem to indicate fully as much affinity with the Planilimbata limestone. Moberg lists, from Tossåsen: — *Orthis christianiae*, *Niobe laeviceps*, and a Cyrtometopus. At Klöfsjö he found *Niobe insignis* and a *Megalaspis* like *M. stenorhachis* Ang. The thickness of this limestone is not stated but one would infer that it was about one meter.

This is succeeded by a green and gray graptolite-bearing shale, which with the limestone below, make a total thickness of fifteen meters. In the shale are lenses and one continuous bed of limestone. The shales have afforded Wiman: —

Pliomera sp.	*Didymograptus filiformis* Tbg.
Megalaspis sp.	*D. hirundo Salter.*
Leptaena sp.	Phyllograptus sp. ind.
Tetragraptus serra.	*Tetragraptus quadribrachiatus.*

In the limestone he found: —

Megalaspis sp.	Ampyx sp.
Niobe laeviceps Dalm.	Orthis sp.

To the writer it would appear that this entire series, including the limestone at the base, belonged to the Phyllograptuschiefer and that we have here Planilimbata limestone and Phyllograptus shales interbedded. If this is the case, then the Dictyonema shales, Obolus sandstone, and the Ceratopyge zones are absent.

The limestone of the section, the Orthocerenkalk, about thirty-seven meters in thickness, is thus subdivided: —

Orthocerenkalk {
- Platyuruskalk.
- Gigaskalk.
- Asaphuskalk.
- Limbatakalk.

Of the Limbatakalk a thickness of only 1.35 meters of dark red limestone was seen, the guide fossil, *Megalaspis limbata* being present.

In the gray Expansuskalk the following typical fossils were obtained, among others: —

Megalaspis heros.	*Lycophoria nucella.*
Asaphus expansus.	*Orthis callactis.*
Ampyx nasutus.	*Orthis calligramma.*

The Gigaskalk is a rather thick-bedded red limestone with *Megalaspis gigas* and grades into the red, coarse-grained Platyuruskalk with the guide fossil, *Asaphus platyurus*, and cephalopods. Above this is a gray limestone, occupying the position of the Chironkalk of other sections, but without fossils.

The Graptolithenschiefer have been investigated fully by Hadding, (60) who found, immediately overlying the unfossiliferous gray limestone, about eight meters of black shale with layers and lenses of dark limestone, the whole characterized by graptolites and trilobites. He has designated this band as the zone of *Climacograptus putillus*, and finds there, among other fossils: —

Didymograptus superstes Lapw.	*Nileus armadillo* Dalman.
Diplograptus perexcavatus Lapw.	*Ogygiocaris dilatata* Brünn.
Climacograptus putillus Hall.	*Trinucleus coscinorrhinus* Ang.
C. scharenbergi Lapw.	*Telephus bicuspis* Ang.
Triarthrus becki humilis Hadding.	*Robergia micropthalma* Linrs.

In slightly higher beds, with less limestone and more shale, he obtained, with others: —

Dicellograptus sextans exilis E. & W.	*Ogygiocaris dilatata* Brünn.
Nemagraptus gracilis remotus E. & W.	*Nileus armadillo* Dalm.

This he designates as the zone of *Nemagraptus gracilis,* and it in turn is followed by similar shales containing *Dicranograptus clingani.* Of the fauna associated with this latter graptolite Hadding gives no list, but the shales containing it are presumably those which Wiman refers to the Chasmopslager, with Chasmops sp., *Asaphus lundibundus* Tqt., *Illaenus fallax* Holm, *I. gigas* Holm, and *Caryocystis granatum* Wbg. According to Moberg the Chasmops limestone is in places found resting on the Orthoceras limestone.

Above the Chasmops zone, but never seen in contact with it, is the Brachiopod shale, from which only a few determinable fossils have been obtained, among them *Encrinurus multisegmentatus* Portl., *Atrypa crassicosta* Dalm., *Leptaena rhomboidalis* Wilckens, and *Plasmopora conferta* Milne Edwards & Haime.

GÄSTRICKLAND.

Nearly all the fossils from this region have been obtained from boulders found in the drift (Wiman, 89), but the record is of considerable interest, from its rather close similarity to the Esthonian development. It appears to be the only part of Sweden where the Lower Cambrian was developed in a region where the Middle Cambrian was absent. The Chironkalk seems also to have been developed, in part, as a Linsenschicht (corresponding to the Upper Linsenschicht of the East Baltic) and the Chasmopskalk appears to have a development comparable to a part of C_1 of the Russian section.

Unfortunately only the strata from the Ceratopyge limestone to the Limbata limestone are found in place.

The Lower Cambrian is indicated by boulders with fragments of Olenellus, Agraulos, Ellipsocephalus, and Mickwitzia.

The Obolus sandstone is indicated by boulders.

Fragments of shale with *Ceratopyge forficula* and two species of Shumardia have been found.

The Ceratopyge limestone is in place on the Island Limon and is .83 meters thick. It contains the usual fossils.

Above this limestone is a clay with glauconite and nodules of limestone. It is 1.17 meters thick and contains few fossils, Lingula ? sp., Acrotreta sp., and Torellella sp. being the only ones reported. This corresponds to the "Glauconite sand" of Esthonia. By Wiman it is united with the Ceratopyge limestone rather than with the Planilimbata limestone above.

The Planilimbata limestone is described as being brownish red in color, with green, violet, and yellow spots and streaks, thus reminding one strongly of the same stratum on the Walchow. It is 3.5 meters in thickness. A rather large fauna is reported, including, *Pliomera actinura, Megalaspis planilimbata, Niobe laeviceps, Harpina excavata,* and *Orthis christianiae,* reminding one of the fauna which Lamansky found at the top of the "Glauconite sand" at Papowka.

The Limbatakalk is a lighter colored rock than the limestone below, and may be gray. It has a thickness of 5.45 meters. *Megalaspis limbata* and other fossils are present.

The Expansuskalk is known from boulders which contain many fossils, including the typical *Asaphus expansus, A. raniceps, Megalaspis acuticauda, M. heros, Lycophoria nucella,* etc.

The Gigaskalk is represented by a single boulder.

The Platyuruskalk is usually found as boulders of red limestone, and along with *Asaphus platyurus* contains many cephalopods, such as *Orthoceras conicum, Vaginoceras wahlenbergi, Lituites lituus,* etc.

The Chiron kalk is found in boulders, sometimes containing "linsen." The fauna contains *Asaphus kowalewski, A. cornutus, Illaenus chiron, I. schmidti,* and *Christiania oblonga,* and distinctly suggests the C_1 of Russia.

The older Chasmopskalk is lithologically like the Chironkalk, and in the boulders are found *Porambonites schmidti, Platystrophia lynx, Christiania oblonga,* Echinosphaerites, *Ptilograptus suecicus,* Climacograptus, and Diplograptus.

The boulders assigned to the younger Chasmopskalk or Macrouruskalk contain among others, *Chasmops maxima, Illaenus fallax, I. oblongatus, Porambonites ventricosus,* and *Platystrophia lynx.*

Boulders of the so-called "Ostseekalk," also occur which, in the North Baltic area, is partly fine-grained "lithographic stone" comparable to the Wesenberg limestone of Esthonia, while other boulders are of a different sort.

Wiman lists the fossils found in a large number of these boulders, which would seem to have been derived from formations very similar to the Kegel, Wesenberg, Lyckholm, and Borkholm of Esthonia.

Interesting species are *Chasmops wesenbergensis, Encrinurus seebachi, Lichas eichwaldi,* and *Clitambonites wesenbergensis,* all of which occur in the Wesenberg at Wesenberg.

Cyclocrinites schmidti and *C. balticus* of course suggest the Kegel, while *Platystrophia lynx* and *Oxoplecia dorsata* occurring together, remind one of the Kuckers.

Encrinurus multisegmentatus, Lichas laxatus, Tetradium wrangeli, Atrypa imbricata, and *Halysites parallelus* are all typical species of the Lyckholm.

Dalecarlia.

Miss Elsa Warburg (84), gives the following section as typical of the region.

Leptaena limestone			
Trinucleus shales	Red Trinucleus shale	15 m.	
	Gray limestone	5–9 m.	
	Black Trinucleus shale	6 m.	
	Masur limestone	9–15 m.	
Chasmops limestone	Macrourus limestone	9 m.	
	Cystidean ls.	15 m.+	
Orthoceras limestone 30–50 m.	Ancistroceras ls.		Upper gray Orthoceras limestone.
	Chiron ls.		
	Platyurus ls.		Upper red limestone.
	Gigas ls.		
	Asaphus ls.		Lower gray limestone.
	Limbata ls.		Lower red limestone.
	Planilimbata ls.	3.08 m.	
Ceratopyge limestone	Ceratopyge ls.	.14–.16 m.	
	Glauconite sand	.10 m.	
	Obolus conglomerate	.15–.80 m.	

In Dalecarlia there is no Cambrian, the Obolus conglomerate resting on the granite. It contains *Obolus apollinis* and is followed by a thin bed of greenish gray glauconitic clay-shale which contains some fragments of Obolus. Above comes a thin bed of glauconitic limestone which contains Obolus fragments and *Lycophoria laevis* Stolley. This Wiman correlates with the Ceratopyge limestone on the basis of the latter fossil.

At a single locality (Skattungbyn) Törnquist found in shales with interbedded slabs of limestone, *Tetragraptus serra, T. quadribrachiatus, Dichograptus octobrachiatus, Phyllograptus densus,* and three species of Didymograptus. The limestone contained *Pliomera törnquisti* Holm, *Megalaspides dalecarlica, Ampyx pater,* and *Agnostus törnquisti* Holm. In general however, the Planilimbatakalk is present, followed by the Limbata limestone. *Megalaspis planilimbata, M. limbata,* *Niobe laeviceps*, and *Nileus armadillo* are found in these strata. The Asaphus limestone contains the typical species, *Asaphus expansus*, *Lycophoria nucella*, etc., and it may be noted that the Lower Linsenschicht is developed in this district. The Gigas and Platyurus limestones have many cephalopods, but few trilobites. Both the Chiron and Ancistroceras limestones contain their typical fossils and are followed by fifteen meters of limestone containing *Chasmops odini*, *Echinosphaerites aurantium*, and *Oxoplecia dorsata*.

The Macrourus limestone contains *Chasmops maxima* Schmidt.

The black Trinucleus shale contains *Trinucleus seticornis*, *Calymene trinucleina* Linrs., *Remopleurides radians* Barr., *Dalmanella argentea* His., and the graptolites *Dicellograptus anceps*, *Diplograptus pristis*, *D. truncatus*, and *Lasiograptus margaritatus*. The gray limestone is reported as containing numerous fossils, which however, occur only as fragments, and I have seen no list.

The red Trinucleus shale contains few fossils. *Remopleurides dorsospinifer*, *Proetus brevifrons*, *Agnostus trinodus*, *Trinucleus*, and *Pseudosphaerexochus laticeps* have been reported. The Leptaena limestone contains a very large fauna, comparable to that of the Lyckholm and Borkholm. There has been a great deal of discussion about the relative positions of the Leptaena limestone and Trinucleus shale in Dalecarlia. Although their faunas are quite different, yet both are characterized by an influx of Bohemian species, and both show the beginnings of a fauna like the Silurian. Furthermore, the presence of *Dicellograptus anceps* and *D. complanatus* are indicative of the youngest Ordovician age of the Trinucleus shales. The Leptaena limestone seems to show the physical characteristics of a "reef," though not perhaps of a coral reef, as Nathorst has suggested.

Västergötland.

The strata of the third belt are best exposed in Västergötland where the Cambrian, Ordovician, and Silurian rocks are practically horizontal and well shown on the sides of small "mountains" in which they have been protected from erosion by a capping sheet of diabase. On account of its quarries, Kinnekulle presents unusual opportunities for studying the Orthoceras limestone and the section there is one of the classic ones in Swedish geology. Throughout this region the Ordovician rests upon Upper Cambrian formations, and the Dictyonema shales are usually either very feebly developed or entirely absent, and the Obolus sandstone has not been reported at all. At most localities the Ceratopyge limestone has a much better development than in the more northern belts, though in a few places it is entirely absent. In most sections, the Planilimbata limestone is absent and the graptolite-bearing shales replace it. The Asaphus limestone of this region is similar to that of Oeland and unlike that of other regions in that *Asaphus expansus* itself is absent from the fauna and the Asaphuskalk is divided into two members by a stratum which is almost entirely made up of the cystid *Sphaeronis pomum* Gyllenhahl.

Kinnekulle.

Ordovician	Brachiopodenschiefer	5 meters.
	Trinucleusschiefer	32 meters.
	Chasmopskalk	10 meters.
	Orthocerenkalk	52 meters.
	Underer Didymograptusschiefer	9 meters.
	Ceratopygekalk	1 meter.

The Ceratopyge limestone is a light gray limestone with light green glauconite and considerable pyrite in certain layers. Beside the typical fossils, which are somewhat abundant, *Lycophoria laevis* Stolley has been reported from this locality by Wiman (90).

The Orthoceras limestone here has been subdivided into four divisions, on the basis of color.

The lower twenty meters are of a deep red color and are known as the "Lower Red." Above is found a band three meters in thickness of light gray limestone, the "Lower Gray." At the top of this there is a sudden change again to deep red limestone and shale, not well exposed except for the two meters at the base, but perhaps thirteen meters thick. This is the "Upper Red," and it is followed by the "Upper Gray," sixteen meters of which could be measured. Fossils are common in the lower part of the Lower Red" and in the "Lower Gray" but rather rare elsewhere, and it does not seem to have been possible so far to make exact subdivisions on the basis of fossils. The color divisions do not, however, seem to correspond to the subdivisions which would be made on the basis of the fauna. The "Lower Gray" includes the "Sphaeronis bank" and with the upper part of the "Lower Red" and the lower part of the "Upper Red," represents the Asaphuskalk. On the basis of fossils it would appear that all the usual zones of the Orthoceras limestone, except the Planilimbatakalk and possibly the Gigaskalk, are present.

Limbatakalk — The greater part of the "Lower Red" probably belongs to this zone. *Megalaspis limbata, Nileus armadillo,* and *Symphysurus palpebrosus* are common here, and a number of other species were collected.

Asaphuskalk — I did not find fossils other than *Sphaeronis pomum* and *Megalaspis heros* very common in this zone. Several other species have been reported, among them *Phaeops sclerops, Cyrtometopus clavifrons, Asaphus raniceps maximus,* etc. The numerous cephalopods assigned to this zone in lists seemed to be derived from the lower part of the "Upper Red" and possibly to indicate the Gigas rather than the Asaphuskalk. Among these are *Vaginoceras wahlenbergi* (Foord), *Bathmoceras linnarssoni* (Ang.), and *Estonioceras proteus* Holm. *Megalaspis gigas* itself has not been found, but the cephalopods mentioned indicate, I believe, its zone.

Platyuruskalk — *Asaphus platyurus* and *Orthoceras tortum* are reported from the upper part of the "Upper Red."

Chironkalk — The "Upper Gray" evidently represents the zones of both *Illaenus chiron* and Ancistroceras. *Illaenus chiron* Holm, *Ogygiocaris dilatata sarsi* Angelin, *Ancistroceras undulatum* Boll, and *Discoceras teres* Eichwald have been reported.

The next formation, the Chasmopskalk, is not exposed on the side of Kinnekulle which I visited, but it is reported as being a dark green graptolite-bearing shale with lenses and layers of impure limestone. The graptolites are not listed, but the limestone is said to contain Chasmops sp., *Remopleurides sexlineatus, Ptychopyge? glabrata, Ampyx rostratus, Echinosphaerites aurantium,* etc. The thickness is ten meters.

The Trinucleus shales, which are not well exposed, are said to be thirty-two meters thick and consist of two shales separated by a thin limestone. The lower twelve meters consist of black and greenish shales separated by two meters of limestone from eighteen meters of the red shale above. Among the forms listed from the upper shales are *Remopleurides radians, Cybele verrucosa, Trinucleus wahlenbergi,* and *Dionide euglypha.*

The Brachiopodenschiefer are said to be represented by twenty-six meters of calcareous shale below, followed by two and four tenths meters of impure sandy limestone. Fossils do not appear to be common, *Dalmanites mucronatus, D. pulchellus,* and *Homalonotus platynotus* being the chief ones reported.

I visited Ålleberg, but found it impossible to get good fossils without spending more time than was at my disposal.

Here the upper Trinucleus shales, also called the Staurocephalus shales, are reported to be very fossiliferous and add *Staurocephalus clavifrons*, *Acidaspis centrina*, and *Phillipsia parabola* to the list of species found at Kinnekulle.

Oeland.

The Ordovician on Oeland rests on Upper or Middle Cambrian strata and the basal member may be either the Dictyonema shale or the Ceratopyge shale. This has been especially well brought out in an instructive diagram by Fearnsides (59). The most complete section of the "Ceratopyge Region" and Cambrian is shown in southern Oeland, where, ignoring subzones, the following strata are found, in descending order.

Ordovician	Glauconite shale. Ceratopyge limestone. Glauconite shale. Shumardia shale. Dictyonema shale.
Upper Cambrian	Peltura limestone. Olenus shale.
Middle Cambrian	Paradoxides forchammeri zone. P. tessini zone. P. oelandicus zone.

It has been shown that in passing northward both the Dictyonema and Shumardia shales pinch out, but at the northern end of the section both come in again, the Dictyonema shale being in certain localities replaced by the Obolus conglomerate. At the southern end of the island the Ordovician rests upon the youngest known beds (zone of *Peltura scaraboides*) of the Upper Cambrian. About midway between the northern and southern ends the Peltura beds disappear and the Ordovician rests for a short distance on the lower part of the Upper Cambrian. From Borgholm for several miles north the Ordovician rests on the next lower zone of the Cambrian, the *Paradoxides forchammeri* zone of the Middle Cambrian. Still further north this gives place to the next lower zone, that of *P. tessini*. The strata of the *Paradoxides tessini* zone are here sandy, and it is where the Ordovician rests on them that the Obolus conglomerate is developed, thus indicating the local origin of the material in the Lower Ordovician.

Finally at the northern end of the island, the Ordovician rests on strata of the lowest of the Middle Cambrian zones, that with *Paradoxides oelandicus*. This section shows very clearly that there was an uplift, tilting, and erosion after the deposition of the Peltura beds of the Upper Cambrian and before the deposition of the Dictyonema shales of the Ordovician, and thus emphasizing once more that the natural place to draw the boundary between the Ordovician and Cambrian is at the base of the Dictyonema shales (or the equivalent Obolus sandstone).

In spite of the considerable amount of work which has been done on Oeland, I am unable to find that any section has been published in which the thicknesses of all the strata have been given.

The youngest strata found in place in Oeland belong to the Lower Chasmops or Echinosphaerites limestone, but the Macrourus limestone, Trinucleus shale, and Leptaena limestone (Lyckholm) are all represented by numerous boulders.

The Echinosphaerites limestone is seen only in northern Oeland, and only *Echinosphaerites aurantium* and *Illaenus chiron* seem to be reported from it.

The Orthoceras limestone is very well developed on the island and it was here that its subdivision on the basis of fossils was first accomplished by Moberg (71). The zones, in descending order are: —

Ancistroceras limestone. The fauna is reported to contain *Ancistroceras undulatum* Boll, Remopleurides, Ptychopyge, *Nileus armadillo*, *Illaenus chiron*, and Orthoceras.

Chiron limestone. This is a limestone containing *Illaenus chiron* Holm, *Ptychopyge aciculata* Ang., *P. testicaudata* Steinh., *Megalaspis pagiata* Tqst., *Ogygiocaris dilatata sarsi* Ang., *Telephus bicuspis* Ang., *Lituites lituus* Monf., and *Didymograptus geminus* His.

Platyurus limestone. This zone has only a few fossils reported, these being *Asaphus platyurus maximus*, *Ptychopyge brachyrachis* Remele, *Rhynchorthoceras* cf. *angelini* Boll., *Echinosphaerites aurantium* Gyllenhahl, and *Hyolithes inaequistriatus* Remele.

From the Gigas limestone, only *Megalaspis gigas* Ang. has been reported.

Upper Asaphus limestone. Moberg states that this is a reddish, rarely white, crystalline limestone with a large fauna of small, mostly undescribed trilobites, and that there is nothing elsewhere which exactly corresponds to this zone. He cites *Nieszkowskia tumidus*, Asaphus sp., *Illaenus esmarki*, *I. centrotus*, *Nileus armadillo*, and *Niobe frontalis* as among the species present.

Below this is the stratum filled with *Sphaeronis pomum* Gyllenh. as at Kinnekulle.

Lower Asaphus limestone. This is a gray limestone from which *Pterygometopus sclerops, Megalaspis heros, Ptychopyge applanata, Niobe frontalis, Illaenus esmarki, Ampyx nasutus, Orthis obtusa*, and *Glyptocystites* cf. *leuchtenbergi* have been reported. *Asaphus expansus* is not found in Oeland.

Holm (65), has described, from a glauconitic gray limestone at Hälludden near Böda in northern Oeland, *Isograptus gibberulus* (Nicholson), *Didymograptus minutus* Tqst., *Tetragraptus bigsbyi* Hall, and *Phyllograptus angustifolius* Hall. The limestone containing these fossils is said to belong to the Lower Asaphus zone, but may possibly be in the Limbata zone.

Limbata limestone. From this zone Moberg reports *Megalaspis limbata, Niobe laeviceps*, two pelecypods, two gastropods, and "*Rhynchonella*" *digitata* Leuchtenberg.

Planilimbata limestone. From this limestone, which is often quite glauconitic, *Megalaspis planilimbata* Ang. and *Holometopus limbatus* Ang. have been obtained.

The Ceratopyge (76) zone is well developed in Oeland, but, as has previously been mentioned, it is variable in its constitution. In the southern half of the island a limestone is present in the upper part, included between two glauconitic shales, and beneath the lower shale is another shale characterized by Shumardia. In the northern half of the island the Shumardia shale is absent, also the limestone, and there remains only a shale bearing Ceratopyge. The total thickness seems to be small, with a maximum of about two meters.

The Dictyonema shale is, as stated above, present in both the northern and southern portions of the island, but absent for a considerable space through the middle. The thickness in the southern part of the island is about two meters.

Scania.

In Scania the strata of the Ordovician consist very largely of graptolite-bearing shales, these shales resting upon the Olenus shales of the Upper Cambrian. At various horizons, however, beds of limestone are intercalated in the shales. No one region presents a complete section, and the following composite section contains some beds which are found only in East Scania, some found only in West

Scania, while others are developed in both regions. The table is an amplification of one given by Moberg (75).

Trinucleus or Upper Dicellograptus shales	Zone of *Phacops eucentra* and *Staurocephalus clavifrons*. Zone of *Ampyx portlocki*.
Chasmops or Middle Dicellograptus shales (with limestone)	Zone of *Pleurograptus linearis*. Zone of *Calymene dilatata* and *Dicranograptus clingani*.
Lower Dicellograptus shales	Zone of *Nemagraptus gracilis*. Zone of *Climacograptus putillus*. Zone of *Glossograptus hincksi*.
Upper Didymograptus shales	Zone of *Didymograptus geminus*. Zone of *Phyllograptus* cf. *typus*.
Orthoceras limestone	
Lower Didymograptus shales	Zone of *Isograptus gibberulus*. Zone of *Phyllograptus angustifolius*. Zone of *Didymograptus balticus*. Zone of *Tetragraptus phyllograptoides*.
Ceratopyge limestone	
Shumardia shale	
Dictyonema shale	

The fauna of the Trinucleus beds has been described by Olin (79), who enumerates many species. Of trilobites forty-three species were listed, and it is of particular interest to note that twelve of these are species common to Sweden and Bohemia. Prominent among such species are *Cheirurus pectinifer* Barrande, *Remopleurides radians* Barr., *Calymene incerta* Barr., *C. pulchra* Beyr., *Phillipsia parabola* Barr., "*Asaphus*" *ingens* Barr., *Trinucleus bucklandi* Barr., *Ampyx gratus* Barr., *A. portlocki* Barr., *A. tenellus* Barr., and *Aeglina rediviva* Barr. In addition to these common species, the genera Aeria, Staurocephalus, and Dionide in themselves suggest the Bohemian fauna. Other important species in the fauna are *Phacops* (*Dalmanites*) *eucentra* Ang., *Agnostus trinodus* Salter, and *Stygina latifrons* Portlock. The important graptolites are *Dicellograptus complanatus* Lapw., and *Diplograptus truncatus* Lapw.

The Chasmops beds contain a rather small fauna, but although there are many limestone bands in the shales, there are fewer trilobites and more graptolites. Olin lists among others *Calymene dilatata*

Tullb., *Remopleurides sexlineatus* Ang., *Ampyx rostratus* Sars, *Dalmanella argentea* (His.), *Corynoides calicularis* Nich., *Dicranograptus clingani* Carr., *Diplograptus quadrimucronatus* Hall, *Climacograptus scharenbergi* Lapw., and *Ptychopyge ? glabrata* Ang. The zone of *Dicranograptus clingani* is at the base of the Chasmops beds, and the zone of *Pleurograptus linearis* at the top.

The fauna of the Lower Dicellograptus shales has been monographed by Hadding (60), who lists the following as characteristic fossils of the thin-bedded gray-black shales which make up the strata of the three subzones in Scania.

Subzone of *Nemagraptus gracilis*.— *Nemagraptus gracilis remotus* Elles & Wood, *Lasiograptus mucronatus* Hall, *Obolus elatus* Hadding, *Plectambonites sericeus restrictus* Hadding.

Climacograptus putillus zone.— *Climacograptus putillus* Hall, *C. caudatus* Lapw., *Dicellograptus vagus* Hadding, and *Dicranograptus irregularis* Hadding.

Glossograptus hincksi zone.— *Glossograptus hincksi* Hopk., *Cryptograptus lanceolatus* Hadding, and *Diplograptus perexcavatus* Lapw.

The Upper Didymograptus beds consist of green and gray shales and the fauna seems to be incompletely known.

In the *Didymograptus geminus* beds.— *D. geminus* Hisinger, *Lonchograptus ovatus* Tullb., *Climacograptus confertus* Lapw., *Pterograptus scanicus* Moberg, *P. elegans* Holm, and species of Diplograptus and Cryptograptus have been reported.

From the lower zone.— *Phyllograptus* cf. *typus*, *Didymograptus* cf. *bifidus*, *Climacograptus* and Cryptograptus are reported. It seems to be a sort of transition zone, in which the Diprionian graptolites which are so abundant in the beds above make their first appearance, but accompanied by some of the survivors of the more ancient fauna.

The Orthoceras limestone is a hard, rather pure, dark blue limestone and is at present inadequately exposed. Angelin (58) described twenty species of trilobites from the quarries at Fågelsång, some of the more important of which are **Ampyx nasutus* Dalm, *Asaphus acuminatus* (Boeck), **Cyrtometopus clavifrons*, **Megalaspis limbata* (Sars and Boeck), **Nileus armadillo* Dalm, *Symphysurus palpebrosus* (Dalm), **Niobe frontalis* Ang., **Pterygometopus sclerops* (Dalm), *Trinucleus coscinorrhinus* Ang. The species marked with an asterisk occur in the Limbata or Expansus limestones of Sweden and in the zones $B_{II\beta}$ and $B_{III\alpha}$ of Russia.

According to Strandmark (81), beds of shale containing graptolites occur between the limestone strata of the Orthoceras limestone, the species found being *Tetragraptus bigsbyi* Hall, *Didymograptus extensus* Hall, and *Phyllograptus cor* Strandmark.

The fossils of the Lower Didymograptus shales have been described by Törnquist (83). These shales are much better developed in southeastern Scania than about Lund.

The zone of *Isograptus gibberulus* contains *Isograptus gibberulus* Nich., *Didymograptus extensus* Hall, *D. patulus* Hall, and *D. mobergi* Tqst.

The zone of *Phyllograptus angustifolius* has *Didymograptus praenuntius* Tqst., *Phyllograptus angustifolius* Hall, and *Tetragraptus pendens praesagus* Tqst.

The zone with *Didymograptus balticus* has a larger fauna, among the species being *Didymograptus constrictus* Hall, *D. balticus* Tullb., *Tetragraptus quadribrachiatus* Hall, *Dichograptus octobrachiatus* Hall, and *Clonograptus subtilis* Tqst.

The lowest zone contains *Tetragraptus phyllograptoides* Linrs., *T. approximatus* Nich., *T. serra* (Brong.), *Didymograptus undulatus* Tqst., and *D. holmi* Tqst.

The Ceratopyge zone is poorly developed in Scania, but both the Ceratopyge limestone and Shumardia shale have been shown to be present, with the usual fossils.

The Dictyonema shales are subdivided into three zones.

C, zone with *Bryograptus kjerulfi* and *Dictyonema norvegica*.

B, zone with *Clonograptus tenellus* in four varieties.

A, zone of *Dictyonema flabelliforme* in which, interstratified with shales, are beds of limestone with *Hysterolenus törnquisti* and *H. levicaudus*.

Very little seems to be known of the thicknesses of strata in Scania. On seeing the outcrops in the field, one receives the impression that they are very small. In a boring made at Stabbarp, northeast of Lund, the Chasmops beds were encountered between eighty-six and ninety-two meters below the surface and shales of the *Phyllograptus* cf. *typus* zone at a depth of 102 meters, thus indicating a thickness of about ten meters for the Lower Dicellograptus shales.

At Jerrestad in eastern Scania Olin measured a section 425 cm. in thickness, all in the Trinucleus zone, and most sections which it is possible to measure are of this order or of less thickness.

Summary.

From the above summary of the sections in the principal Ordovician belts of Sweden, certain facts should appear.

It will be noted that the Dictyonema zone is present in almost all sections, and that the character of the deposit is controlled by the underlying beds, a fact which in itself is evidence of a cessation of sedimentation, uplift, and erosion. In North Oeland, where the basement beds are the *Paradoxides tessini* sandstone, an Obolus sandstone is developed, and in the northern belt, Dalecarlia-Gästrikland, where the older strata are pre-Cambrian crystallines and Lower Cambrian sandstones, one finds Obolus conglomerate and Obolus sandstone. That the Obolus sandstone is of the same age as the Dictyonema shale is of course abundantly proved by their interstratification with each other at several places in Esthonia. In southern Oeland, in Scania, and at Christiania, where the underlying strata are the black shales and limestones of the Upper Cambrian, the Dictyonema zone is developed as a shale without sand and has even, in places, irregular layers of limestone.

Over a certain area, in Nerike and part of Västergötland, the Dictyonema zone is absent. Thus, at Kinnekulle the Ceratopyge limestone rests upon the limestone and shale of the Upper Cambrian, at Ekedalen the Planilimbata limestone rests directly on the Upper Cambrian, and at Hunneberg the Ceratopyge limestone rests on the Upper Cambrian limestone in most places, though in some spots about three inches of shale belonging to the Dictyonema zone have been reported. The arrangement of these localities free from Dictyonema deposits suggest a large, low lying island composed of uplifted Upper Cambrian strata, which was progressively submerged during Lower Ordovician time, but not completely covered till toward the end of Planilimbata time. Correlated with this may be the distribution of the Lower Didymograptus shale.

As has already been pointed out repeatedly by the Swedish geologists, when the Lower Didymograptus shales are present in any section, the Planilimbata limestone is absent, and when the latter is present, the former is absent. This has naturally led to the deduction that the two formations were deposited at the same time and owe their dissimilar faunas to the very different conditions of sedimentation. On this point, the evidence, though strong, does not seem to be absolutely conclusive. It would seem that, should it happen that limestone were found interstratified with the graptolite shale, it should contain some at least of the species found in the strata where limestone only was deposited. In Dalecarlia, Holm (62), found a trilobite fauna in limestone interstratified with the Lower Didymograptus shales. Six species of trilobites were identified, and five of the species, *Pliomera törnquisti*, *Megalaspides dalecarlica*, *Ampyx pater*, *Agnostus törnquisti*, and *Trilobites brevifrons* were new and are all restricted to this one locality. The sixth species, *Niobe laeviceps* Dalman is not a guide fossil, ranging from the Ceratopyge limestone to the Asaphus limestone. The pygidium of *Pliomera törnquisti* is not known but the cephalon and thorax show that it is not a true Pliomera but a Cyrtometopus allied to the forms found in the Ceratopyge limestone. Similar species are, however, found in higher strata. Megalaspides is not yet definitely placed outside this occurrence in Dalecarlia. Wiman (88), has described *Megalaspides nericiensis* from the Shumardia shale in Nerike, but there is some doubt as to whether this Shumardia shale belongs to the Ceratopyge zone or to a horizon in the Planilimbata limestone.

Wiman (89), also reports pygidia of Megalaspides from boulders of Planilimbata limestone in Gästrikländ, and Lamansky (29) described *Megalaspides schmidti* from a pygidium found in B_1 at Papowka. Identifications based on pygidia alone seem rather unsafe in this genus, the pygidium being so Asaphus-like. The genus has not hitherto been suspected in the Ceratopyge limestone, but at Hunneburg I found a large hypostoma of the "forked" type in the same strata with Euloma and Symphysurus, and as no other member of the Asaphinae is known at so low a horizon, it of course suggests Megalaspides. *Agnostus törnquisti* and *Trilobites brevifrons* are of no value in the discussion. *Ampyx pater* is similar to *Ampyx nasutus* of the Limbata and Asaphus limestones rather than to the species so far described from the Ceratopyge limestone.

The fauna found by Holm in Dalecarlia is then not very useful in the correlation of the Lower Didymograptus beds with the Planilimbata limestone. It contains no species restricted to the Planilimbata limestone, and the general composition of the fauna is such that, lacking a guide fossil of either, it could be referred to the strata either above or below it. Over most of Dalecarlia the Planilimbata limestone is present, but very poor in fossils. In Jemtland, as indicated on page 208 there does seem to be some mingling of the species of the Lower Didymograptus shales with those of the Planilimbata limestone.

The Didymograptus shale is absent from Oeland, is best developed in eastern Scania, present in western Scania, well developed in Västergötland at Hunneberg and Kinnekulle, and present though less developed in other places. As previously noted, the shale is absent at Ekedalen, and Fearnsides has pointed out that the shale thickens in going away from Sköfde and Ekedalen. Munthe gives the following thicknesses at places on the Sköfde sheet of the Geologic Map: Ulunds, .6 meters, Bäckagarden .23 meters, Kapplunda .2 meters, Persberg, absent, Skultorps Norra .9 meters. At Klefda in the western Falbygden region, not far from Falköping, the thickness is three meters, at Hunneberg, eleven meters (capped with diabase), and at Kinnekulle, ten meters. As to fauna, it is only in eastern Scania that the four subfaunules are developed. Here one sees, in descending order:— (4), zone of *Isograptus gibberulus*, (3), zone of *Phyllograptus angustifolius*. (2), zone of *Didymograptus balticus*. (1), zone of *Tetragraptus phyllograptoides*.

In connection with the thinning of the shales toward Ekedalen it is important to note that at Hunneberg one finds the zones 1 and 2, at Kinnekulle 1, 2, and 3, the Limbata limestone succeeding the shale, but in the thin sections in the Sköfde area *Phyllograptus angustifolius* is reported as the most common graptolite, indicating the presence there of zone 3. In other words, the shale has thinned by the loss of the lower members, thus showing overlap in that direction and sustaining the idea that there was an island of Cambrian strata here in early Ordovician times. The Ceratopyge formation also thins in this direction, as shown by Munthe's measurements in the Sköfde sheet: Ulunda .3 meters, Backagarden .12, Kapplunda .4, Persberg .3, Skultorps Norra .9 and Skultorps Sodra .15. It has been argued (Wiman, 90) that the foot of conglomeratic and glauconitic limestone resting on the Cambrian at Ekedalen represented the Ceratopyge limestone, but this seems very improbable both on faunal and stratigraphic grounds.

It has been suggested that the lower part of the Lower Didymograptus beds replace the Ceratopyge limestone in certain regions, but the very general occurrence of the *Tetragraptus phyllograptoides* faunule in shales resting on the youngest of the Ceratopyge zones negatives this idea. That the Limbata limestone does replace the upper part of the shale is, however, readily shown by the occurrence of the fauna of the *Isograptus gibberulus* subzone in or above the Limbata limestone on Oeland.

In connection with the development of the Orthoceras limestone, certain things should be noted. For instance, in those sections where the Orthoceras limestone is thickest, as on Oeland or at Kinnekulle, *Asaphus expansus*, the guide fossil of the "Expansusschicht" is absent; and there is found, above the strata containing a fauna which includes a part of the species usually found associated with *Asaphus expansus*, a layer with such quantities of the cystid *Sphaeronis pomum* as to make a veritable cystid reef. No such reef is seen where *Asaphus expansus* is present, as in Östergötland or the Christiania district. Both Sphaeronis and *Asaphus expansus* are reported from Dalecarlia, but, according to Törnquist the former species is exceedingly rare, and not quite typical, and that district will probably not prove to be an exception to the general rule.

Very little has been done toward working out the details of the various sections in the Orthoceras limestone, so that the sections at Kinnekulle and Oeland are really the only ones which can be compared. On Oeland, one finds above the bed with *Sphaeronis pomum* the Upper Asaphus limestone, with numerous undescribed trilobites. Moberg states that this zone occurs nowhere else and it certainly is not present at Kinnekulle, where a cephalopod fauna is found in the red limestone above the Sphaeronis bed. This cephalopod fauna is that normally found in the Gigas limestone, and it seems that there is in the Oeland section a zone which is lacking at Kinnekulle. Whether the absence of *Asaphus expansus* from the thick sections is explainable by the predominance of red sediments, or whether the Expansus beds are actually absent is not at present apparent. It should be observed that the extra thickness in these great sections is largely accounted for by the unusual development of the Planilimbata limestone, though of course the added zones above the Gigas limestone have something to do with it.

In Oeland, at Kinnekulle, and in Delarne, one finds considerable limestone above the Gigas limestone, which by the Swedish geologists is included in the Orthoceras limestone. This limestone contains three faunal zones, according to the Swedish geologists, but the faunas of the three seem very much alike. The lower zone contains *Asaphus platyurus* and *Echinosphaerites aurantium*, fossils found in $C_{1\alpha}$ of Russia, and *Illaenus chiron* is found in $C_{1\beta}$ of that country, but the other guide fossils are mostly species not found in Russia. The presence of *Didymograptus geminus* in the middle zone of the three in Oeland is noteworthy, for it serves to complete the parallelization of the Scanian and Oeland sections.

The presence of Ogygiocaris, which seems to have an exceedingly narrow vertical range, in the Nemagraptus zone in Jemtland and in the

Chiron limestone of Kinnekulle and Oeland, serves to indicate that the upper part of the Orthoceras limestone in these localities is the equivalent of the *Nemagraptus gracilis* shale as well as the Geminus shale. And the correlation of the Chasmops limestone with the graptolite shales of the *Dicranograptus clingani* and *Pleurograptus linearis* zones is assured by the presence of several species common to the two types of deposits.

CORRELATION OF THE AMERICAN WITH THE EUROPEAN FORMATIONS.

In attempting a correlation over such a distance one is of course obliged to depend very largely on fossils; and it is necessary to assume an hypothesis which all the evidence seems to support, namely, that cosmopolitan faunas reach their wide distribution within a very short space of time. In the present case, it is necessary to depend very largely upon the graptolites which seem to be more widespread than any of the other organisms. Graptolites are, of course, almost absent from Russia, so that it is necessary to correlate the Russian with the Swedish sections by means of other fossils. The trilobites, being best known, have been used most, but in certain cases species of brachiopods, cystids, or cephalopods have proved of prime value.

After making many groupings of the formations and testing many tentative correlations, it has seemed that the most logical arrangement is secured if the principal weight is given to the graptolites. It appears that these organisms had spread very much more rapidly than any of the other animals, except for a few thin-shelled brachiopods and trilobites which may have been dispersed by the same agency as the graptolites. When relatively short distances are in question, it seems that the bottom dwelling animals were able to keep pace in their migrations with the graptolites, at least sufficiently closely so that we detect no difference in the geological record, but when long distances are traversed, the bottom animals lag very considerably behind. Striking cases are those of Shumardia, which preceded the first Tetragraptus fauna in Scandinavia, and reached America only with the last Tetragraptus and the first Diplograptus, and of Echinosphaerites, which preceded the *Nemagraptus gracilis* fauna in Scandinavia and followed it in America.

Lower Ordovician.

The drawing of the lower boundary of the Ordovician at the base of the shales with *Dictyonema flabelliforme* instead of at the top of that zone is due to Moberg (73), and seems to have been suggested to him in the first instance by the discovery low in the zone of a trilobite (*Hysterolenus törnquisti*), which bore a marked resemblance to Ceratopyge. The suggestion was a remarkably good one and is borne out both by faunal and stratigraphic relations.

On the faunal side, one may cite the occurrence in this zone of the oldest graptolites, thus marking the introduction of an entirely new faunal element. Also, a few species are common to the shales of the upper part of the zone and the Shumardia or Ceratopyge shales at the base of the Ceratopyge zone.

The best argument is, however, based upon the evidence which the geographical distribution of the deposits show of a great transgression of the sea at this time, and the evidence of preceding erosion. This evidence has already been detailed above, and it is necessary here only to call to mind the conditions in the several regions.

In Esthonia the Dictyonema shale is interstratified with the Obolus sandstone, leaving no doubt that the two are of the same age. The Obolus sandstone, with conglomerate at the base in places, rests on Lower Cambrian sandstone.

In Oeland, in passing from north to south, the base of the Ordovician (Obolus sandstone, Ceratopyge shale, and Dictyonema shale) rests on successively higher and higher strata, varying in age from lower Middle Cambrian to upper Upper Cambrian, the Obolus sandstone being developed over the Middle Cambrian Tessini sandstone.

In Dalecarlia, the Obolus sandstone overlaps onto the crystalline rocks, but eastward in Gästrikland boulders of both Lower Cambrian sandstone and of Obolus sandstone indicate that conditions there were formerly as in Esthonia.

These facts show very clearly that at the end of the Cambrian there was uplift accompanied by some, though probably not great tilting, and a considerable amount of erosion, before the deposition of the strata of the Dictyonema zone.

In America, the *Dictyonema flabelliforme* fauna is known from a number of localities in the northeastern part of the United States and Canada, but nowhere are these strata found in such position that their relation to other strata can be definitely determined.

Ruedemann (115) has summarized all that is known about its occurrence in this country, and he, Matthew (104), and Hahn (103), have pointed out the similarity of development of subzones at St. John, New Brunswick, and Scandinavia. Present evidence indicates that the *Dictyonema flabelliforme* fauna is the oldest of the Ordovician faunas in both Europe and America, though there is a possibility that the strata with the Acerocare fauna in Scania and the Niobe fauna in Wales may have to be added to the Ordovician series.

Brögger (99), attempted a correlation of the Ceratopyge zone with certain strata in America but though his paper was extremely suggestive, no very definite correlations were at the time possible. And even now, we know no typically developed Ceratopyge fauna in America. Walcott (120) has described a trilobite from the lower part of the Goodsir formation of British Columbia as *Ceratopyge canadensis*, and though it seems very doubtful if this is a Ceratopyge, it probably belongs to the Tremadoc fauna. The writer has described from the same region *Hemigyraspis mcconnelli* (110), a form indicative of the Asaphellus beds of the Tremadoc of Wales. I have also described, from the Tribes Hill of New York and the equivalent Stonehenge of Pennsylvania, species of Hemigyraspis and Symphysurus also indicative of the Ceratopyge fauna. This latter correlation is of considerable importance, for the Stonehenge is the lower member of the Beekmantown in western Central Pennsylvania. The Hemigyraspis fauna occurs in the upper twenty-seven feet of the Stonehenge, which has a thickness of 662 feet, and above the Stonehenge are 2570 feet of strata before the top of the Beekmantown is reached. In the lower Stonehenge, a Dictyonema has been found (Hahn, 103).

In Russia the Ceratopyge zone is probably not represented. There is of course a temptation to make the Glauconite sandstone the equivalent of the whole Ceratopyge zone, especially as one sees in Sweden glauconitic sands associated with the Ceratopyge limestone. In Dalecarlia there is a glauconite sand beneath the Ceratopyge limestone, but in Gästrikland, where the section is very like the Russian section, there is a glauconitic sand above the Ceratopyge limestone, and it seems very probable that this sand is an extension of that so well developed in Esthonia. It seems to belong with the Limbata limestone above. This sandstone is thickest in Esthonia, and probably indicates an emergence in that district so that there was some erosion, perhaps accounting for the absence of the Dictyonema shale at Narwa, and shore or shallow water conditions in Esthonia during the deposition of the Lower Didymograptus shales in Scandinavia.

The absence of the Lower Didymograptus fauna in Esthonia seems explainable on the basis of lack of suitable physical conditions. It is well known that the abundance of graptolites increases in proportion to the degree of fineness of grain and amount of carbonaceous material in shale. The Middle and Upper Cambrian strata of Sweden are vast storehouses of very fine grained, highly carbonaceous shale. Possibly these deposits extended at one time nearly or quite to Esthonia. As has been shown, the end of the Cambrian was a time of considerable denudation, and the Cambrian sediments could furnish a vast supply of black mud, which, on account of its fineness, could be transported long distances. Hence the widespread deposit of Dictyonema shales. The shales however, rapidly covered the sinking land, and were in turn covered, over large areas, by the Ceratopyge limestone, so that, when the Lower Didymograptus fauna occupied this region, only limited areas of Cambrian strata, such as the island already mentioned in Västergötland at Ekedalen and Sköfde, were subject to erosion. There may have been a small rather general uplift at this time, indicated in Sweden by the change from limestone to shale sedimentation, and in Esthonia by the glauconite sand. To consider the Dictyonema and Lower Didymograptus black shales as reworked Cambrian shales seems more plausible than to think of them as due to certain peculiar conditions under which black shales seem usually to be formed. In any event, Esthonia was at this time outside the territory which could be supplied with reworked upper Cambrian muds, while sands were immediately available and the graptolite fauna did not reach the region.

To correlate the Russian "Orthoceras limestone" (B_{II}, B_{III}) with any formation in America on the basis of graptolites is rather complicated but it can, I think, be done fairly satisfactorily. In the first place there is general agreement, on the evidence of numerous species of trilobites, cephalopods, and brachiopods common to both, that the zones from the Planilimbata limestone to the top of the Gigas limestone in Sweden and Norway are the equivalent of the zones B_{II} and B_{III} in Russia. As to the exact correlation of the subdivisions there is not so great unanimity of opinion, but as to the bounding formations, the Planilimbata limestone and the Gigas limestone on one side; and the Glauconite limestone ($B_{II\alpha}$) and the Orthoceras limestone ($B_{III\gamma}$), on the other, there can be no question.

In Sweden the position of this limestone in respect to the graptolite succession is definitely fixed. We know that the Planilimbata limestone succeeds the Ceratopyge zone, and that the *Tetragraptus phyllo-*

graptoides zone succeeds the Ceratopyge zone, and precedes the Limbata limestone. The Planilimbata limestone can not be older than the oldest of the Tetragraptus zones. On Oeland, *Isograptus gibberulus*, and other graptolites of the Lower Didymograptus zone occur in the Lower Asaphus limestone, which Lamansky correlates with the Russian zone $B_{III\beta}$. In Norway the Gigas limestone is followed by black shale with *Didymograptus geminus*. On Oeland, the Gigas limestone is followed by the Platyurus limestone, and that in turn by the Chiron limestone, which contains *Didymograptus geminus*. The top of the Gigas limestone, and likewise of the Orthoceras limestone ($B_{III\gamma}$) of Russia, is therefore somewhat older than the *Didymograptus geminus* fauna. In Scania, the *Didymograptus geminus* fauna is found in shales resting on other shales containing *Phyllograptus* cf. *typus* and *Didymograptus* cf. *bifidus*. This in turn rests upon the Orthoceras limestone of that region. This limestone, in turn follows shale with the *Isograptus gibberulus* fauna. The limestone contains a large trilobite fauna which, however, in our incomplete knowledge of the faunas of the Swedish "Orthoceras limestone," it is not safe to correlate directly with the faunas of other regions. Since it follows the zone with *Isograptus gibberulus*, one would naturally correlate the Orthoceras limestone of Scania with the Lower Asaphus limestone of Oeland. If this correlation is correct, then the *Phyllograptus* cf. *typus* beds of Scania would appear to represent some or all the Upper Asaphus limestone, Gigas limestone, and Platyurus limestone of Oeland. But for reasons to be given later, the Platyurus limestone is probably to be eliminated from this list. This does not of course, prove definitely that the Gigas limestone is of the age of *Phyllograptus* cf. *typus*, though there is a strong presumption, since both are older than the zone with *Didymograptus geminus*. Fortunately however, Schmidt found Phyllograptus in B_{III} in Esthonia, and Phyllograptus sp. has been reported from above the Gigas limestone of Norway.

The limestone of the Gigas and lower zones, down to the bottom of the Planilimbata zone of Sweden, and the zones B_{II} and B_{III} of Russia must therefore be placed within the range of Phyllograptus in the graptolite succession. It remains now to see what that means in the American sequence.

The occurrence of the Tetragraptus-Phyllograptus-Didymograptus fauna in the shales of the Lévis formation of Canada has long been known, and recent work by Ruedemann (115) and the writer (111) has shown the order of succession of the faunules within the formation. The relation of the Lévis to the Beekmantown of America is, however, not yet fully settled, though evidence accumulated by Dr. Ulrich (119) shows that the Lévis and Beekmantown are probably of the same age. This evidence is based largely on the occurrence of graptolites in dolomite with a Beekmantown fauna near Smithville, Lawrence Co., Arkansas. At this locality, *Phyllograptus ilicifolius, P. angustifolius, Didymograptus bifidus,* and *D. amplus* have been found with brachiopods and fragments of trilobites. In a bed just above the one containing graptolites, *Plethospira cassina, Subulites obesus,* and *Eurystomites kellogi* were found. These latter fossils are characteristic of the Cassin limestone and occur about midway in the section of the Beekmantown on the eastern side of Lake Champlain. In Vermont the strata of the Beekmantown are principally limestone and dolomite, the total thickness being about 1200 feet, the top being unknown, as the upper beds were eroded before the deposition of the Chazy. The top of the Cassin limestone is 470 feet below the top of the Beekmantown and the formation is 100 feet thick. No graptolites have been found in the Beekmantown in Vermont. There seems no doubt however, that the mollusks cited above are characteristic of the Cassin and, therefore, the graptolites found in Arkansas belong in the Cassin or in an older formation, and are surely Beekmantown in age.

In England all the species of Phyllograptus and Tetragraptus are in the Arenig, and in America the various zones of the Lévis contain species of these genera, and all the zones are so knit together by common species that it seems quite evident that all belong to a continuous series. *Phyllograptus ilicifolius* is a long ranging species at Lévis, but *Didymograptus bifidus* is found in shale in the middle of the section. The fossils in Arkansas thus suggest that the middle of the Lévis corresponds to the middle of the Beekmantown, and that the two are approximately equivalent.

From these considerations one feels justified in concluding that all the strata characterized by Phyllograptus, *Didymograptus bifidus,* and Tetragraptus, both in Europe and America, are equivalent, and represent the deposits of Beekmantown (Arenig) time. It has been pointed out in the previous detailed discussions that the Dictyonema and Ceratopyge zones of Scandinavia are related to the strata overlying them, so that the final correlation would be that the formations from the Packerort to Kunda (inclusive of both) (A_2–B_{III}) of Russia are equivalent to the strata from the Dictyonema zone to the Gigas limestone of Scandinavia and to the Canadian (Beekmantown) of America.

Lower Middle Ordovician.

As has already been stated, there is throughout northern Europe, a distinct change in fauna after the deposition of the last of the strata correlated above with the Beekmantown of America.

In Russia, in Västergötland, and on Oeland, where there is a continuous section of calcareous strata this change is less marked than in Norway, where the Gigas limestone is succeeded by black shales, but it is shown as well in Scania where the strata of the section are mostly shales.

In Russia, C_1 marks the introduction of the Echinosphaerites-Christiania fauna, in which nearly all the species are different from those found in the strata below. In Norway, the Gigas limestone is followed by black shales with the *Didymograptus geminus* fauna, and in Scania the shale with *Phyllograptus* cf. *typus* is followed by shale with *Didymograptus geminus*. On Oeland, the Gigas limestone is followed by limestone with *Asaphus platyurus,* and that in turn by limestone with *Illaenus chiron* and *Didymograptus geminus*. Throughout Scandinavia then, the zone with *Didymograptus geminus* is the earliest zone of the series succeeding the Arenig. In Great Britain likewise there is a zone of *Didymograptus murchisoni,* a species practically identical with *D. geminus*, which is considered as the lowest zone of the Llandeilo. In Great Britain there are two species of Dicellograptus in the fauna of this zone, and no species of either Phyllograptus or Tetragraptus are present. The latter statement is true also of Scandinavia, and the zone is known at all localities as being the oldest in which there is a profusion of diplograptids. This zone is not yet positively identified in America. Ruedemann has provisionally correlated the Bed 7 of the Deep Kill section of New York with the European strata containing the *Didymograptus murchisoni* fauna, but although Phyllograptus and Tetragraptus were not found by Ruedemann, the remainder of the fauna is so nearly identical with the fauna of the *Diplograptus dentatus* zone of the Lévis section, where both Tetragraptus and Phyllograptus do occur, that I am inclined to believe that the zone 7 belongs with the Lévis.

In Scandinavia the *Didymograptus geminus* beds are followed by the Lower Dicellograptus shales, containing the zones, in ascending order, of *Glossograptus hincksi*, *Climacograptus putillus*, and *Nemagraptus gracilis*. Unfortunately, a great deal remains to be done before a very satisfactory correlation of the Echinosphaerites limestone of Norway with the Lower Dicellograptus shale of Sweden can be made. Echinosphaerites has not yet been reported directly associated with a graptolite fauna containing diagnostic species. The shales with the Lower Dicellograptus faunas are found at the north in Jemtland and at the south in Scania, in both of which places Echinosphaerites is absent.

On Oeland, Echinosphaerites occurs at two horizons. The first occurrence is in the Platyurus limestone, in strata below the Chiron limestone, which contains *Didymograptus geminus*. The second appearance is in Chasmops limestone, which is the horizon in which it is found at Kinnekulle and in Västergötland generally.

At Kinnekulle, Echinosphaerites is found in the Chasmops limestone, which is a formation consisting of limestone interstratified with shale, the shale holding undetermined graptolites. Very little seems to be known of the detailed distribution of the faunas in the Chasmops formation in Västergötland but the general consensus of opinion seems to be that the Echinosphaerites is confined to the lower portion. Of the trilobites listed from the Chasmops limestone in Västergötland and Dalecarlia, *Remopleurides sexlineatus, Ptychopyge glabrata, Ampyx rostratus,* and *Agnostus trinodus* all occur in the zone of *Dicranograptus clingani* in Scania. The zone of *Dicranograptus clingani* is the one next above the zone of *Nemagraptus gracilis,* both in Scania and in Jemtland.

In Gästrikland and Dalecarlia conditions seem to be somewhat similar to those in Russia, for in Delarne the Platyurus limestone contains a layer practically made up of "linsen," and boulders from Gästrikland referred to the Chiron limestone contain "linsen" and such typical Russian species as *Asaphus kowalewski, A. cornutus,* and *Christiania oblonga.* In other boulders, said to be lithologically like the Chiron limestone, but referred by Wiman to the Chasmops limestone, *Echinosphaerites aurantium,* and *Christiania oblonga* are found.

In the Christiania district of Norway, as has already been stated, the Gigas limestone is succeeded by black shale and limestone, forty to forty-five meters thick, with *Didymograptus geminus.* Other significant fossils found here are *Asaphus platyurus, Ogygiocaris dilatata,* and *Lituites lituus,* fossils found in the Platyurus, Chiron, and Ancistoceras zones at Kinnekulle and on Oeland, leaving no doubt as to the correlation of these strata. Following this zone which is known as 4 aα, is the zone 4 aβ, the zone of *Echinosphaerites aurantium.* Here the strata are dark blue to black limestone and dark shale interstratified and the thickness is about fifty meters. The Echinosphaerites are confined to certain layers and various trilobites are present, among them, *Ogygiocaris dilatata, Nileus armadillo, Trinucleus coscinorrhinus*, all of which are found in the zones of *Climacograptus putillus* and *Nemagraptus gracilis* in Jemtland.

It would seem from the comparison of sections that Echinosphaerites appeared in northern Europe first in Oeland and migrated thence into Norway and Russia. Its occurrence in Oeland in strata older than those containing *Didymograptus geminus* shows definitely that it antedated there the first appearance in Norway, for in the latter country it is found first in strata resting upon those containing *D. geminus*. In Russia the sequence of faunas, Echinosphaerites first and then Echinosphaerites and Christiania, is exactly the same as in Norway, strongly suggesting that the Echinosphaerites did not reach that country sooner than it did Norway. There is physical evidence in Russia of an interruption of sedimentation after the Kunda formation was deposited, while there is but slight evidence of a break between the Reval and the Kuckers. This, coupled with the faunal evidence, particularly the total absence of the Ogygiocaris fauna in Russia, indicates such a correlation as I have shown in the table.

The Ogygiocaris fauna is Norway is found best developed in 4 aα but many of the species pass over into 4 aβ, among them the *Ogygiocaris dilatata* itself. In Jemtland Ogygiocaris is found in the zones of both *Climacograptus putillus* and *Nemagraptus gracilis* and serves to connect the Nemagraptus zone with the first Echinosphaerites zone in Norway (4 aβ).

Normanskill.

The *Didymograptus geminus* fauna has not yet been identified in America, but the *Nemagraptus gracilis* fauna is well known from the Normanskill shale of New York. At the type-locality, however, the Normanskill shale is very much faulted, folded, and twisted, and its correlation with the formations of the standard section is not yet established. Ruedemann at first considered it to be of early to Middle Trenton age but later inclined to correlate it with the Black River. Ulrich (119) has considered it still older, placing it below the Lowville, but above the typical Chazy, making it a member of his Blount group, which he places between the Stones River and the Lowville.

In Virginia typical Lower Dicellograptus faunas (*Nemagraptus gracilis* zone) have been seen in sections where the sequence is normal at two localities, but in neither is the evidence fully established. In looking over material collected by Drs. E. O. Ulrich and George W.

Stose from thin-bedded dark limestone at the Mattheson limestone quarry near Abingdon, Virginia, I found numerous specimens of a Robergia very like *R. micropthalma* and a Telephus like *T. bicuspis.* These trilobites were associated with diplograptid graptolites which Dr. Ulrich assures me are of typical Normanskill species. Such an association is found in the *Climacograptus putillus* zone of the Lower Dicellograptus shale at Anderson, Jemtland, Sweden, and the association is too remarkable a coincidence to indicate anything other than approximate contemporaneity of the two formations. Stose gives the following section at Abingdon.

	Feet.
Sevier shale — Eden fossils in upper and Trenton fossils in lower part.	800
Moccasin limestone. Red limestone with few fossils.	400
Ottosee limestone, with Echinosphaerites.	200
Athens shale. Calcareous shale and dark blue shaly limestone above; dark gray fissile shale below. The fauna mentioned was found in lower part.	500–600
Stones River limestone.	400
Knox dolomite (of Beekmantown age).	

From this section it may be seen that the Normanskill is younger than some part of the Stones River, and considerably older than the Sevier shale, the lower part of which seems to be of Trenton age, though to what part of the Trenton it appertains is not yet evident.

The other section containing the Normanskill fauna was described by Powell (105) and is near Salem, Virginia. He records the following, in descending order: —

		Feet.
	Medina sandstone (Silurian).	
8.	Shale, very fossiliferous. No list of fossils.	1200
7.	Blue to black shale and limestone.	300
6.	Red and gray sandstone without fossils.	400
5.	Blue and black limestone without fossils.	500
4.	Black carbonaceous shale with numerous graptolites. 32 species are listed, including *Nemagraptus gracilis, Climacograptus putillus* and *Dicellograptus sextans. Triarthrus* and *Trinucleus* are also recorded.	560
3.	Coarse grained dark limestone with bands of marble.	250
2.	Pure "dove" colored limestone with a Tetradium and large gastropods.	50
1.	Cherty magnesian limestone with *Maclurites.*	500

Professor Powell was good enough to spend three days in showing the writer this section, and my interpretation of it differs somewhat from that in his published account. The cherty magnesian limestone at the base (zone 1) appears to belong to the Beekmantown, not the Chazy, and Ophiletas were found in the upper beds. Zone 2 is a fine-grained buff limestone with numerous gastropods and some trilobites. At the base is a conglomerate with pebbles of magnesian limestone and chert in a calcareous matrix. This formation is to be correlated with the Mosheim of southwestern Virginia and eastern Tennessee, and that in turn is correlated with the lower part of the Stones River of central Tennessee.

The coarse-grained dark limestone of zone 3 is very fossiliferous, some of the genera present being Hormoceras, Amphilichas, Illaenus, Isotelus, Orthis, Dinorthis, Plaesiomys, Oxoplecia, Leptaena, Plectambonites, and Solenopora, besides numerous bryozoans. This fauna is much more like that of the Black River of New York than it is like any fauna of the Chazy in the typical region, Oxoplecia and Plectambonites in particular being unknown in the Chazy. On the other hand, the fauna is more or less like that of the Holston and Lenoir of eastern Tennessee, and these latter formations seem to be of Middle Chazy age. The relation of this formation to the one below is exactly like the relation of the Leray to the Lowville in New York. The line of separation between the dark, impure limestone above and the pure light-colored limestone below is a sharp one, and yet the top of the one formation and the bottom of the other are combined to form a single layer; a so-called "welded contact."

The Athens shale (zones 4 and 5) is a dark fossiliferous shale in the lower portion, and passes rather gradually into an almost entirely unfossiliferous blue limestone above. *Nemagraptus gracilis* and Didymograptus occur in the lower part of the shale, while Dicellograptus, Climacograptus, and the beautiful synrhabdosomes of Diplograptus are most abundant at about the middle. *Ampyx americanus* appears to begin its range with these latter fossils, being here accompanied by a Triarthrus, and extends up into the limestone of zone 5. In the upper part of its range, I found it accompanied by Cryptolithus, Robergia, and Acrothele. The Athens is plainly equivalent to the Normanskill of New York, and the Lower Dicellograptus shales of Sweden.

Zone 6, the Tellico sandstone, is practically unfossiliferous here as elsewhere. Upon it rests a thick mass of shale with some thin-bedded limestone. This formation is generally called the Sevier in southwestern Virginia, and has not yet been studied in sufficient detail to permit of exact subdivision or correlation. In this section, the lower 500 feet or thereabouts appear to be of Trenton age, while the remainder of the strata are probably Eden and Maysville, but where to draw the line between the two is not yet fully determined. Professor Powell is engaged upon a further study of the section, and will soon be able to give more detailed information.

The lower 100 feet of the part of the Sevier referred to the Trenton consists chiefly of shale, and its fossils are Calymene, Dalmanella, and Rafinesquina. The next 125 to 150 feet consist of alternations of thin-bedded limestone and shale, the latter predominant. In this zone *Cryptolithus tessellatus* is common, associated with *Ceraurus pleurexanthemus,* Calymene, Sinuites, Plectambonites, and Dalmanella. About 100 feet above this zone, hemispheric bryozoans are common, and with them are *Parastrophia hemiplicata,* Dinorthis, and Sinuites. The Parastrophia is not the pauciplicate form found in the Lower Trenton of New York and Quebec, but like the form in the Middle and Upper Trenton of Ontario. In this same zone Professor Powell found some graptolites which appear to be *Lasiograptus eucharis,* a Middle Trenton and Utica graptolite in New York. The upper 100 feet of the strata here referred to the Trenton consist almost entirely of thin-bedded blue limestone, and at the very top are great numbers of Zygospira, Plectambonites, and Pholidops, while some layers are full of gastropods.

The rocks above the Trenton consist principally of shale, becoming more and more sandy toward the top. In the middle are some massive calcareous strata, and an occasional layer of limestone is met with at various horizons. The whole reminds one very much of the Lorraine of New York, and the fossils emphasize that impression. The upper 100 feet, more or less, belongs to the Bays sandstone, and has the typical fauna, *Platystrophia* (or *Orthorhyncula*) *stevensoni* Grabau, *Byssonychia walkerensis* Grabau, *B. radiata* (Hall), and other pelecypods and brachiopods. This fauna is generally considered to be of Upper Maysville age.

The section, as interpreted above, seems to place the Normanskill definitely as post-Middle Chazy and pre-Trenton, the Athens and the Tellico together occupying the position usually filled by the Upper Chazy and Black River. Since the Normanskill graptolites occur in the lower part of the formation, they would probably be of Upper Chazy age.

Echinosphaerites and Christiania faunas.

The position of the Echinosphaerites beds in the American Ordovician section can not be said to be definitely established. The knowledge which we have of these beds is due largely to Dr. Ulrich and to Dr. Bassler (98), and by the former of these investigators the fossil is reported as occurring at three horizons, one below and two above the Lowville.

The evidence concerning the younger of these occurrences, in so far as it has been published, may be found in the description by Stose, of the Chambersburg — Mercersburg map-area, and in the Revision of the Palaeozoic Systems by Ulrich. The following section (here rearranged) is given by Stose (118).

		Feet.
10.	Soft yellowish green sandstone with few fossils, said to be of Eden species	1200±
9.	Black carbonaceous shale, with *Climacograptus spinifer, Corynoides calicularis, Leptobolus insignis, Triarthrus becki*, etc., in lower 100 feet.	800±
8.	Shale and thin-bedded limestone with many small fossils, including *Triarthrus becki, Cryptolithus tessellatus*, Ampyx, Caryocaris, etc.	150±

All the above strata are referred to the Martinsburg shale.

7.	Calcareous shale and shaly limestone, with *Christiania trentonensis, Plectambonites asper, P. pisum*, Oxoplecia, *Parastrophia hemiplicata*, etc. Echinosphaerites in the upper ten feet.	150±
6.	Dark gray, largely thin-bedded limestone with *Nidulites favus*, Ampyx, *Plectambonites asper*, etc.	237±
5.	Dark gray limestone in which Echinosphaerites is very common, Ampyx, Receptaculites, Oxoplecia, and brachiopods also common.	60±
4.	Grayish dense thin-bedded limestone with *Tetradium cellulosum, Zygospira recurvirostris*, etc.	150±

These limestones above are all grouped as the Chambersburg limestone.

3.	Thin-bedded, pure, fine-grained limestone with *Leperditia fabulites.*	275±
2.	Massive pure limestone and layers of black chert. *Maclurites magnus, Tetradium syringoporoides, Ampyx halli,* and brachiopods.	200±
1.	Massive and thin-bedded pure and magnesian limestone. Beekmantown limestone.	600±

Zones 1 to 3 are correlated with the Stones River.

According to Dr. Ulrich, the section near Chambersburg, Pa., has a "lower Echinosphaerites bed," forty to fifty feet in thickness, resting upon about 150 feet of limestone referred by him to the Lowville (4 of section on preceding page). This Echinosphaerites bed, which lithologically is a very earthy limestone is said by Ulrich (119, p. 322) to be overlain by about 300 feet of hard dark limestone with Nidulites, and that in turn by 270 [1] feet of strata in which thin beds of limestone are interstratified with thick beds of shale. These strata are characterized by Christiania. A few feet below the top is the upper Echinosphaerites zone, and here Christiania is most abundant. The Christiania beds are capped by the Martinsburg shale, which contains Triarthrus, Cryptolithus, and Corynoides.

At Strasburg, Virginia, still according to Ulrich, the lower Echinosphaerites bed rests upon a cherty limestone 100 feet thick, and the Echinosphaerites is accompanied by brachiopods and bryozoans which suggest to him a correlation with the Decorah shale of Minnesota (called Black River by Ulrich). Above this zone are the massive beds with Nidulites, 207 feet thick, followed by a forty foot bed of argillaceous gray limestone and calcareous shale, containing Echinosphaerites (upper zone) and brachiopods, with other fossils characteristic of the Christiania fauna. This bed is followed above by 300 feet of thin-bedded argillaceous light gray limestone and calcareous shale, passing at the top into true shales. This limestone is referred to the Martinsburg, since it has, in shaly beds ten to thirty feet above the base, *Corynoides* cf. *C. gracilis, C. calicularis, Climacograptus spinifer, Leptobolus insignis,* etc.

This manner of occurrence is in striking accord with that in Norway, where Echinosphaerites occurs first in stage 4aβ without Christiania, and then at a higher horizon 4bα with that fossil.

At Bellefonte, Penn., according to observations made by Mr. R. M.

[1] These figures are given on the authority of Ulrich and do not agree with the sections published by Stose.

Field and the writer, a zone of dark limestone, containing such typical Leray (Black River) species as *Columnaria halli* and *Maclurites logani*, is followed by more argillaceous limestone containing Echinosphaerites and a large number of other fossils. Christiania has not yet been found in the Bellefonte section, but this section does definitely show that the Echinosphaerites zone is there younger than the Leray — Black River of New York. As shown by Mr. Field, there is essential agreement between the section at Bellefonte and that at Chambersburg and Strasburg, so that all three of these occurrences of Echinosphaerites may be dated definitely as post-Leray.

According to Ulrich (119), the Kimmswick limestone at Thebes, Illinois, and Cape Girardeau, Missouri, has at the top a bed of crystalline limestone, from five to thirty feet in thickness, which contains Echinosphaerites and Comarocystites, among other fossils. The Kimmswick at this locality can not be definitely placed in the section, except that it is post-Lowville. In the Nashville dome in Tennessee a formation correlated by Ulrich with the Kimmswick and containing Echinosphaerites has been found at Aspen Hill, where it is forty feet thick, and followed by the Hermitage, the Bigby, and the Catheys formations. The contact with the underlying formation is not shown but Ulrich states that there is no doubt that it rests upon the Carters, which is the equivalent of the Leray or Lowville of New York so that it may safely be stated that here again the Echinosphaerites bed is post-Leray. At this locality we have the Echinosphaerites without Christiania, and the zone apparently corresponds to the lower zone at Chambersburg, Strasburg, and Bellefonte. In this case the formation containing the Echinosphaerites is limited above by the Hermitage formation, a formation which can not be correlated with any New York formation, but which corresponds to the Logana of Kentucky and is also found at Bellefonte above the zone of Echinosphaerites. The Hermitage is followed above by the Bigby limestone, which contains a fauna corresponding to that of the Prasopora zone, or Middle Trenton of New York and Ontario. The Kimmswick limestone, and the corresponding Echinosphaerites zone in Pennsylvania and north-central Virginia, may therefore be correlated with some confidence with the lower part of the Trenton of New York.

The other occurrence of Echinosphaerites in the Appalachian region is in the Ottosee formation of southwestern Virginia and eastern Tennessee. Dr. Ulrich believes that the Ottosee is older than the Lowville, and, if this can be shown to be correct, then this zone is older than the two already discussed. A good section showing the position of the Ottosee in relation to the other formations is that given by Bassler (98) from outcrops on Walker Mountain north of Marion, Smyth Co., Virginia. The strata there named "Holston marble and associated strata" were later named Ottosee by Ulrich.

	Feet.
Sevier shale.	
Brown to olive and gray shales.	1500
Moccasin limestone.	
Impure, argillaceous limestone.	300
Ottosee formation.	
(e) Unfossiliferous drab shales.	40
(d) Nodular limestone and yellowish to gray shales holding many Bryozoa.	30
(c) Massive gray and pink marble with numerous Bryozoa, Solenopora and *Stylaraea parva*.	30
(b) Clayey nodular limestone and shale. Some of the layers are crowded with Receptaculites.	50
(a) Massive crystalline limestone.	40
Athens shale.	
Dark to black shale with black slaty limestone at the base. Linguloids and trilobites are abundant at the base.	500±
Stones River formation.	170
Knox dolomite (Beekmantown in age).	

The Stones River of this section is stated by Bassler to contain in its upper part a typical Chazy fauna, though the only species mentioned are *Maclurites magnus* and *Stylaraea parva*.

The trilobites mentioned as occurring in the Athens are not listed, but it is known that this formation in at least two places in Virginia carries the *Nemagraptus gracilis* (Normanskill) fauna. (See p. 234).

From the Ottosee Bassler lists Echinosphaerites, *Batostoma sevieri*, *Scenellopora radiata*, *Diabolocrinus vesperalis*, *Solenopora compacta*, and *Receptaculites biconstrictus*. It is quite true that this fauna is somewhat unlike that of the Echinosphaerites zone in the other localities, but there is nothing in the composition of the fauna itself to indicate that it is older than Black River. *Receptaculites biconstrictus* is similar to the Black River *R. occidentalis*, which occurs with Echinosphaerites at Chambersburg and Bellefonte, Pa., Batostoma is principally a Black River genus, and the other fossils of the Ottosee have a rather indefinite value in correlation.

The Moccasin is a nearly unfossiliferous red limestone of Middle Ordovician age, the only fossils cited being *Plectambonites sericeus* and *Dalmanella testudinaria*.

The Sevier shale is reported to be of Trenton age in its lower part, and Utica and Eden in the upper. From this particular section it is not possible to say more of the age of the Ottosee than that it is older than the Middle Trenton and younger than the Normanskill. In Tennessee, according to Ulrich, (119, p. 556) the Ottosee is to be seen beneath the Lowville. "Although not so thick as at Knoxville, Bulls' Gap and Athens, the Ottosee is yet well and unmistakably developed in the two Ordovician belts between Clinch Mountain and Clinch River in Hawkins and Hancock Counties (Tennessee). In both bands the Holston underlies the Ottosee and over that is the Lowville. The outcrops referred to are located in the Northern third of the Morristown quadrangle.

"In the band lying just north of War Ridge the Holston rests on a very uneven floor of Knox dolomite. It varies from 0 to 120 feet or more. The Ottosee, which overlies it unconformably, is also thin and variable in thickness, the observed variations ranging from 35 to 100 feet. Above the latter, apparently again with a stratigraphic hiatus between them, comes a series of fine-grained, thin-bedded limestone, 400 to possibly 600 feet in thickness, that is correlated with the Lowville. This determination is made chiefly on the basis of fossils, the lower 50 feet containing fine examples of a fasciculated Tetradium, referred provisionally to *T. cellulosum*, and the upper 200 feet *Beatricea gracilis*. This is followed by the typical Moccasin."

The only possible question about these statements must be as to the identification of the Ottosee, no evidence being presented as to the basis of its correlation with the Echinosphaerites-bearing Ottosee of Virginia. Echinosphaerites is, however, reported from eastern Tennessee. A disturbing element in this matter is that *Christiania subquadrata* Hall is reported by Bassler (Bull. 92, U. S. N. M.) as coming from the Ottosee of Blount Co., Tennessee.[1] If the Ottosee is pre-Lowville, then we have three zones with Echinosphaerites. The oldest, found only in southwestern Virginia and eastern Tennessee, may be pre-Lowville and have, locally, Christiania as well as Echinosphaerites. The second is immediately post-Leray-Black River, and contains Echinosphaerites without Christiania. This is found in northern Virginia, eastern and central Pennsylvania, central Tennes-

[1] Dr. Ulrich tells me this should be Lenoir.

see, eastern Missouri, and southern Illinois. The third and last occurrence of Echinosphaerites is in a zone about 300 feet above the strata containing the second occurrence, and in this highest zone Christiania is abundant. This zone is found so far only at Strasburg, Virginia, and near Chambersburg, Pennsylvania. It is correlated with the Trenton of New York.

Pleurograptus linearis has been found in the typical Utica of this country and here as in Europe marks a younger zone than that of *Dicranograptus clingani*. Since, in Sweden, the beginning of the range of *Dicranograptus clingani* is to be correlated with the last appearance of Echinosphaerites, and, in Norway at least, the sedimentary record from the *Didymograptus geminus* beds to the end of the Echinosphaerites beds seems complete, it would seem that we must parallel the Echinosphaerites-Christiania beds of Europe with the Trenton and Black River of America. The Middle and Lower Chazy would be of the age of the *Didymograptus geminus* strata. Since the Jewe and Kegel of Russia, seem to correspond to the zone of *Dicranograptus clingani* and so to the Middle Trenton of America, and since there is no radical change in fauna through the Jewe, Kegel, and Wesenberg more than could be expected of various faunules in a single formation; and since further these formations contain some species found in the Trenton of America, it seems that they most probably are to be correlated with the American Middle and Upper Trenton, but extending probably on into the equivalent of the Eden and perhaps Maysville, though there is evidence of a very considerable break between the Wesenberg and the Lyckholm, which is Richmond:

Middle Ordovician.

In Europe there is no distinct separation of the Lower Middle Ordovician beds from those above, and I have used the above caption merely to separate the discussion of the *Didymograptus geminus* and *Nemagraptus gracilis* faunas from those which follow.

The most complete section is that in Norway where the zone of the first Echinosphaerites is followed by the zones of 4b, characterized by Chasmops and Echinosphaerites. Zone 4bα, a shale with thin layers of limestone, all very dark in color, is characterized especially by Christiania and *Chasmops conicopthalma*. Here one finds also species of Ampyx, Lonchodomas, Remopleurides, Tretaspis, Sphaerocoryphe, Calymene, Conularia, and Echinosphaerites. The zone is forty to forty-five meters thick about Christiania.

The strata of 4bβ consist of thin-bedded dark blue limestone with shaly partings and the thickness is about twelve meters. Here one finds much the same fauna as in 4bα, but Christiania has disappeared. A Platystrophia of large size, like the *P. lynx* of the Itfer and Jewe was collected from this zone.

4bγ is another zone of much shale and some thin-bedded limestone, with a variable thickness, usually from thirteen to sixteen meters. *Chasmops extensa* is the guide fossil and Brögger has not listed any others. I myself found no fossils worth saving at this horizon.

4bδ, the last of the zones of 4b, consists of interbedded dark blue limestone and almost black shale, the thickness being about twelve to seventeen meters. In this zone are found the last and the largest of the Echinosphaerites, and a very Trenton-like fauna, in which I was interested to note two common American forms, a Parastrophia somewhat like *P. hemiplicata*, and a Triplecia very like *T. nuclea*. *Cyclocrinites spasskii* makes its first appearance in Norway at this horizon, and Illaenus, Ampyx, Trinucleus, Remopleurides, Cybele, Chasmops, etc., are present. Brögger (94) correlates this zone with the Jewe of Russia with which I entirely agree, only adding that the presence of *Cyclocrinites spasskii* suggests also the Kegel. It seems quite possible that there is a break in the sedimentary record in the Christiania district at this point.

In the Christiania area the zone 4bδ is followed by the zone 4cα, the beginning of the *Trinucleus seticornis* fauna, correlated with the Trinucleus shales of Sweden. In the district Mjösen, north of Christiania, however, Holtedahl (97) has found a different succession, and strata which, in my opinion, are to be intercalated between 4bδ and 4cα, and not to be correlated with 4c as Holtedahl has done. As in Christiania, stage 4 in Mjösen is introduced with an Ogygiocaris zone, containing *Ogygiocaris dilatata, Didymograptus geminus* and many other species, this zone having a probable thickness of twenty to thirty meters. This is followed by a thin zone of calcareous shales, three to four meters thick, and it in turn by black shales with limestone nodules, the thickness unknown. The fauna consists very largely of gastropods and cephalopods, of which many species are listed. The fauna is connected with the preceding zones by the presence of *Ogygiocaris dilatata,* but no species pass on into the overlying strata. We have here probably a very unusual development of the strata of the age of the zone of *Nemagraptus gracilis.*

The next formation, B_1 of Holtedahl's section, consists of practically unfossiliferous shales and thin-bedded sandy limestone which passes above into B_2, sandy limestone and shale containing *Coelosphaeridium cyclocrinophilum*. In the upper part of the same formation is a large fauna which includes many species found in the Jewe of Esthonia. *Cybele grewingki* Schmidt, *Chasmops marginata* Schmidt, *Porambonites schmidti* Noetling, *Coelosphaeridium cyclocrinophilum* Roemer and *Mastopora concava* Eichwald are among the striking species which Holtedahl lists as common to the two regions. The thickness of this formation is unknown but it must be over forty meters.

Then follow two very fossiliferous zones both characterized by an abundance of Cyclocrinites, and making a total thickness of about twenty-three meters. These formations have a fauna entirely comparable to that in the Kegel of Esthonia. Holtedahl lists the following species found in both B_3 and the Kegel:—

Basilicus kegelensis Schmidt, *Chasmops maxima* Schmidt, *Chasmops bucculenta* Sjögren, *Pterygometopus kegelensis* Schmidt, *Bucainiella lineata* Koken, *Leptaena* aff. *schmidti* Törnquist, *Platystrophia biforata* Schlotheim, *Triplecia insularis* Eichwald, *Cyclocrinites oelandicus* Stolley, *C. vanhoeffeni* Stolley, and *C. balticus* Stolley.

Holtedahl correlated these latter zones, B_3a and B_3b, with the Trinucleus shales of Sweden, the Trinucleus shales and Isotelus limestone of Norway, and the Kegel and Wesenberg of Esthonia. In regard to the correlation with the Trinucleus shales, Holtedahl himself says that there are only two species, *Illaenus linnarssoni* and *Remopleurides dorsospinifer* common to the two. Neither of these species is a guide fossil, *Illaenus linnarssoni* in particular having a very long geological range. It is worthy of note that none of the Bohemian species which make so important a part of the fauna of the Trinucleus zone of Sweden and the Christiania district is found in B_3 of the section in the Mjösen district, but the fauna is strictly of the Russian type and belongs to another basin. In this case, the difference can hardly be due to difference in facies, for the Trinucleus beds of the Christiania district contain a large amount of limestone; not a sandy limestone, it is true, but neither is the Kegel a sandy limestone. Furthermore, we are not here dealing with graptolites or other fossils highly sensitive to environmental conditions, but with general faunas.

In Jemtland, the Trinucleus shales appear to be absent, and among the boulders of "Oestseekalk" are found many of the characteristic fossils of the Kegel and Wesenberg limestones, indicating that these formations may in former times have extended across this northern region. In Dalecarlia, however, which is well to the north, the Trinucleus shales are well developed, and contain the typical southern fauna. The Kegel and Wesenberg are certainly older than the Trinucleus shales.

The Chasmops limestone of Sweden has been little studied except for the work of Olin on the trilobites in Scania, and the time is not yet ripe for accurate correlations. The Upper Chasmops or Macrourus limestone of Dalecarlia contains such species as *Chasmops maxima* Schmidt, found in Russia in the Jewe and Kegel, while the lower Chasmops limestone of the same region contains such typical Kuckers and Itfer fossils as *Echinosphaerites aurantium*, *Chasmops odini*, and *Oxoplecia dorsata*. The Chasmops limestone is therefore correlated as indicated by these fossils. As mentioned above, there are certain trilobites which serve to connect the Chasmops limestone with the shales in Scania containing *Dicranograptus clingani* and *Pleurograptus linearis*. Between the zone of *Nemagraptus gracilis* and that of *Dicranograptus clingani*, there is, it seems, a considerable gap, so that the section in Scania is far from complete.

Zone of Dicranograptus clingani.

In southern Sweden the zone of *Nemagraptus gracilis* is succeeded by the zone of *Dicranograptus clingani*, or as it is sometimes called, the Middle Dicellograptus beds.

These beds, have recently been studied in great detail on Bornholm, politically an apanage of Denmark, but geologically in the Scanian province. Hadding (61) has recognized four subzones on this island. These are in descending order:

4 Zone with *Climacograptus styloideus* Lapworth.
3. Zone with *Dicranograptus clingani* Carruthers.
2. Zone with *Amplexograptus vasae* (Tullberg).
1. Zone with *Climacograptus rugosus* Tullberg.

Among the fossils of zone 4 may be mentioned, beside the name fossil, *Glossograptus quadrimucronatus*, *Diplograptus truncatus*, *Dicellograptus pumilis*, *Leptograptus flaccidus macer*, and inarticulate brachiopods.

Zone 3 has a large fauna, including among others, *Amplexograptus vasae*, *Climacograptus brevis*, *Dicellograptus forschammeri*, *D. pumilis*, and *Corynoides curtus*. There are also several inarticulate brachiopods and *Dalmanella argentea*.

In zone 2 the only graptolites are *Amplexograptus vasae* and *Corynoides curtus.*

Zone 1 contains *Climacograptus scharenbergi* and *C. rugosus.*

In America the zone of *Dicranograptus clingani*, though that species itself is not present, is found in the shales of eastern New York and Canada. These shales were long called Utica, but Ruedemann (113 and 117) has shown that they are older and equivalent to the calcareous Trenton of Central New York. The shales are also involved in the mass of the so-called Hudson River shales in the Hudson Valley. They are the Cumberland Head shales of the Champlain Valley, the Snake Hill shales of the Hudson Valley, and the Canajoharie shales of the Mohawk Valley.

At Canajoharie, the type-locality for the formation of that name, Ruedemann (117) found the following sequence of faunas:—

At the base, are seventeen feet of dark blue fossiliferous limestone with interstratified shale beds. This limestone is basal Trenton and contains the Cryptolithus fauna in the limestone, while the interstratified shale afforded *Corynoides calicularis, Diplograptus amplexicaulis,* and *Mesograptus mohawkensis*, so that we here have an indication of the fauna of the shaly equivalent of the Glens Falls limestone.

Above this comes the Canajoharie shale, which is strongly calcareous in its lower portion, becoming truly argillaceous above.

In the lower sixty-five feet of the Canajoharie, *Diplograptus amplexicaulis* is the only graptolite, while in a zone between 65 and 120 feet above the base of the formation, *Corynoides calicularis, Diplograptus putillus,* and *Lasiograptus eucharis* are added. Brachiopods, pelecypods, and crustaceans are fairly common in both zones. In the zone from 115 to 150 feet above the base *Glossograptus quadrimucronatus cornutus* appears, associated with some of the previously mentioned graptolites. These pass up through the next 120 feet, to 270 feet above the base of the formation. *Triarthrus becki* is not noted until a height of 190 feet above the base of the formation, when it appears suddenly in great numbers.

Thus, combining the information obtained from the Canajoharie and Sprakers sections — these localities are only about two and one half miles apart — Ruedemann made out four faunal zones.

4. Zone of *Climacograptus spiniferus, Diplograptus vespertinus,* and *Lasiograptus eucharis.*
3. Zone of *Lasiograptus eucharis, Trocholites ammonius,* etc.
2. Zone of *Glossograptus quadrimucronatus cornutus, Corynoides calicularis,* etc.

1. Zone of *Diplograptus amplexicaulis*, *Corynoides calicularis*, etc. As one goes further west the limestone at the base of the section becomes thicker and it is found that the graptolites characteristic of the lower part of the shale at Canajoharie are not present, but the lowest of the shale beds, resting on the limestone, contain species which first appear high in the section at Canajoharie.

At Dolgeville, half way between Canajoharie and Utica, where the lower 200 feet of the Trenton is limestone, the first shale bed contains *Glossograptus quadrimucronatus*, *Climacograptus typicalis*, and *Lasiograptus eucharis*, which is interpreted by Ruedemann as being a fauna younger than that of zone 2 above, since *Climacograptus typicalis* is best developed in the still higher Utica shales.

In the typical Trenton at Trenton Falls, *Diplograptus amplexicaulis* is a rather common graptolite in the lower part of the formation, where it is found in limestone. (See Fig. 1, p. 257).

The typical Utica, or zone of Pleurograptus linearis.

At Holland Patent and South Trenton, New York, where the black shale of the typical Utica rests upon the top of the Trenton limestone not far from the type-locality, the following fauna has been found: —

Callograptus compactus (Walcott),
Climacograptus typicalis Hall,
C. putillus (Hall),
Mastigograptus simplex (Walcott),
M. tenuiramosus (Walcott),
Pleurograptus linearis (Carruthers),
Leptograptus annectans (Walcott),
Dicranograptus nicholsoni Hopkinson,
Glossograptus quadrimucronatus Hall. var.
Lasiograptus eucharis also occurs nearby and in beds a little higher in the section.
L. bimucronatus timidus Ruedemann.

This may be taken as the typical Utica fauna, but it may be remarked that it has not been found in its entirety, at any other locality. Associated with these graptolites one finds also *Triarthrus becki* and *Cryptolithus tessellatus*. It will be noted that in the above fauna there are certain graptolites which are found at a lower horizon, such as *Climacograptus typicalis*, *Glossograptus quadrimucronatus*, and *Lasiograptus eucharis*. *Mastigograptus simplex* has until recently been found only at Holland Patent and the immediate vicinity. *Lasiograptus bimucronatus timidus*, *Leptograptus annectans*, and *Mastigo-*

graptus tenuiramosus, are restricted to that locality and the Fulton of the Cincinnati district. *Pleurograptus linearis*, which is so important a fossil in northern Europe, is in this country known only from a single specimen found at Holland Patent. *Callograptus compactus* is also known only from Holland Patent. There are varieties of *Dicranograptus nicholsoni* in older shales, but the typical form is restricted to the horizon of the Utica of Holland Patent. It is found also in the Fulton shale of the Cincinnati district and near Saratoga. In attempting a correlation of any other fauna with that of the typical Utica it must be borne in mind that some of the typical species of that fauna are so rare that but few specimens are known. Practically all the species of graptolites which are not restricted to the locality at Holland Patent are species of considerable vertical range. The occurrence, however, of *Pleurograptus linearis* stamps that fauna as younger than that with *Dicranograptus clingani* and probably equivalent to the upper Chasmops shale of Sweden.

The Fulton shale at the base of the Eden at Cincinnati contains a graptolite fauna very like that at Holland Patent. Some of the species are: —

Mastigograptus tenuiramosus (Walcott),
Leptograptus annectans Walcott,
Dicranograptus nicholsoni Hopkinson,
Climacograptus typicalis Hall,
C. putillus (Hall),
Lasiograptus bimucronatus timidus Ruedemann.

Associated with these are *Cryptolithus tessellatus* and *Triarthrus becki*. In higher beds of the Eden of the same region one finds *Dictyonema arbuscula* Ulrich, *Mastigograptus gracillimus* (Lesquereux), *Chaunograptus gemmatus* Ruedemann, and *Climacograptus typicalis* Hall.

From the above we may derive that the more widespread species of the typical Utica (*Pleurograptus linearis* fauna) are *Mastigograptus tenuiramosus*, *Leptograptus annectans*, *Lasiograptus bimucronatus timidus*, and *Cryptolithus tessellatus*. *Climacograptus typicalis*, *Dicranograptus nicholsoni*, and *Triarthrus becki* are also species which though not strictly restricted to the Utica, are to be found in every outcrop of that formation.

From the above it is evident that while some of the graptolites have a long range in the black shales of New York, there are species which seem to be characteristic of certain horizons. Thus we have in the shale equivalent of the Lower Trenton, *Corynoides calicularis* and *Diplograptus amplexicaulis,* in the shale equivalent of the remainder of the Trenton (as exhibited in the Trenton Falls section) *Lasiograptus eucharis, Glossograptus quadrimucronatus* var., *Climacograptus putillus,* etc., and in the shale above the Trenton of Trenton Falls, *Leptograptus annectans* and the other fossils listed above.

If we now return to the Lower Mohawk Valley, we find above the Canajoharie shale the Schenectady formation, composed largely of sandy shale and sandstone, but containing some graptolites and other fossils. Our knowledge of this fauna is due almost entirely to Dr. Ruedemann. That author has correlated the Schenectady with the Upper Trenton, but, to my mind, on very inadequate evidence. Some of the more important fossils of the formation are:—

Azygograptus sp.
Mastigograptus cf. *M. simplex* Walcott.
Diplograptus vespertinus Ruedemann.
Climacograptus bicornis ultimus Ruedemann.
C. typicalis Hall.
Lasiograptus eucharis Hall.
Rafinesquina ulrichi James.
Trocholites ammonius Conrad.
Triarthrus becki Green.
Cryptolithus tessellatus Green.

and numerous eurypterids.

Ruedemann states that this fauna bears a Utica aspect, but that the graptolites point as much toward the Canajoharie fauna as toward the typical Utica. In this connection we must note the absence of *Diplograptus amplexicaulis, Corynoides calicularis,* and *Glossograptus quadrimucronatus.* It is true that none of the graptolites listed are confined to the Utica of the Holland Patent type, but both *Climacograptus typicalis* and *Lasiograptus eucharis* are very abundant in the typical Utica. The presence of a Mastigograptus comparable to *M. simplex* also suggests Utica, as does the presence of Eurypterida. Finally, and most important, is the presence of *Cryptolithus tessellatus,* a fossil which to Dr. Ruedemann suggested the Trenton age.

The geological range of *Cryptolithus tessellatus* seems to be quite generally misapprehended. It is frequently thought of as a fossil which occurs almost anywhere in the Trenton, whereas, as a matter of fact, it is restricted to certain definite horizons and is not everywhere present.

The earliest appearance of Cryptolithus in New York is very near the base of the Trenton, where it is exceedingly abundant in the Glens Falls formation. At this horizon it is very abundant near Quebec, at Montreal, in the Champlain Valley, and the Mohawk

Valley, in all of which places it occupies a thin formation, its vertical range never exceeding forty feet. A very few specimens have been found in the lowest layers at Trenton Falls, but it is absent from more northern outcrops of the Trenton. It is not found in the Trenton anywhere in the region of New York west of the Adirondacks, it is absent from the Trenton of Ontario and Quebec west of Montreal, and it is absent from Minnesota. The second occurrence in New York is not in the Trenton, but in the typical Utica, at Rome and the vicinity. It occurs also in the Frankfort, and still higher, in the Pulaski.

In the vicinity of Quebec the second appearance of Cryptolithus is in the light-colored sandy shale about 400 feet above the top of the limestone of the Trenton, and above the dark "Utica" shale.

At Bellefonte, Penn., the earliest appearance of *Cryptolithus tessellatus* is, as in New York, just above the limestone containing the Leray fauna, and it reappears in the upper fifty feet of the 600 foot Trenton section, at the point where the limestone begins to pass over into shale, and just before the first appearance of *Triarthrus becki.* In Kentucky, Cryptolithus appears first in the Logana (Hermitage), only a few feet above the base of the Trenton, and does not reappear till the Cynthiana, just at the top of the Trenton or base of the Eden. On the Ohio River at Cincinnati it is in the Cynthiana, and the Lower Eden, and appears again in the Maysville.

The occurrences are so exceedingly alike, and there is so great an indifference displayed as to the character of the sediments, that I am inclined to look upon Cryptolithus as an exceedingly good horizon marker. If this be the case, then the Schenectady formation is to be correlated with the Utica, and, probably, the Frankfort.

CORRELATION OF THE TRENTON IN AMERICA.

One great obstacle to any correlation of the kind attempted in this study is the fact that we have as yet reached no satisfactory solution to the problems presented by our American Ordovician strata. By far the best correlation tables for the Ordovician are those recently presented by Drs. Ulrich and Bassler. My own differs radically from theirs, and I am therefore compelled to traverse the principal outlines of the subject in justification of the departures which I have made from former schemes.

It is only some twenty years since it became known that there is in the United States more than one kind of "Trenton." Naturally, the history of the attempts to correlate the various kinds of "Trenton" has been made in that time. The most troublesome of the still unsolved problems is the exact relation of the "Trenton" (Rysedorph, Chambersburg, Quebec City, Chickamauga, Sevier, etc.) of the Appalachians to the "Trenton" (typical Trenton of New York, Trenton of Ontario, Minnesota, etc.) of the interior.

The Appalachian Trenton, if I may so call it, extends from the destroyed end of the range at Gaspé in intermittent aligned exposures as far as Georgia. A beginning on the description of its fauna was made by Ruedemann (114) in his paper on the fossils in the pebbles of the Rysedorph conglomerate, but practically nothing more has been done along that line. Until the fauna is described the problem will remain unsolved. We have, however, some inkling of what the fauna is like, and notice that while in general similar to the Trenton faunas of the interior, it differs in containing Echinosphaerites, Christiania, Nidulites, Tretaspis, and Lonchodomas in abundance, these genera being unknown in the interior Trenton. Many undescribed forms are also peculiar to this Appalachian area, but the above familiar genera are sufficiently striking. An entering wedge in the solution of the problem has been driven home by the demonstration that the principal zone of Echinosphaerites is, over wide areas, resting upon the Leray-Black River. Here there is then a point of contact between the Appalachian and interior provinces. Dr. Ulrich will agree to this, but will include practically all of the limestone at Chambersburg, for instance, with the Nidulites, Christiania, and Upper Echinosphaerites zones, in the Black River. To show that they represent the Trenton is a difficult, perhaps at present, impossible task, but I shall endeavor to present my reasons for so regarding them. To do this, I must start with the section in New York and proceed by a roundabout western route to reach eastern Pennyslvania.

Trenton in New York.

The type-locality is in New York State, at Trenton Falls. The section at Trenton Falls is unsatisfactory, in that the formation is not there exposed to a low enough level to show the formation upon which the Trenton rests. But a few miles east of Trenton Falls, at Rathbone Brook, is another section which supplements the one at

Trenton Falls, and zones 2 and 1 of the section below are to be understood to be exposed only in small part at Trenton Falls, but completely at Rathbone Brook. The Utica is likewise not exposed directly at Trenton Chasm, but at several places in the immediate vicinity.

Composite section (Raymond, 112). Zones 7 to 3 and upper part of 2 exposed at Trenton Falls.

		Feet.
8.	Thin-bedded black and brown carbonaceous shale with *Triarthrus beeki, Cryptolithus tessellatus, Pleurograptus linearis* and many other graptolites. The contact with the limestone below is sharply defined and there are no transition beds. Utica shale (typical). Thickness about 300 feet.	
7.	Light gray, coarse-grained lithified coquina in thick beds. *Rafinesquina deltoidea, Hormotoma trentonensis* and other fossils.	26
6.	Thin-bedded blue limestone with shaly partings. *Rafinesquina deltoidea* the common characteristic fossil.	92
5.	Thin-bedded blue limestone with thick shaly partings. *Prasopora simulatrix* and other common Trenton fossils abundant.	100
4.	Thin- and thick-bedded limestone, dark in color and fine-grained. *Diplograptus amplexicaulis* a common fossil.	35
3.	Thin-bedded dark limestone with *Triplecia extans* and other fossils.	20
2.	Thin-bedded dark limestone with some inter-bedded coarse-grained layers. *Cryptolithus tessellatus* the characteristic fossil. *Trematis terminalis, Platystrophia trentonensis, Calymene senaria* and many other fossils present.	41
1.	Thin-bedded gray limestone with an abundance of *Dalmanella rogata,* and some other fossils.	32

The Leray-Black River is beneath 1. I wish to call especial attention to the fact that there are here two zones of *Cryptolithus tessellatus;* one in the forty-one feet of limestone near the base of the section (this is the Glens Falls limestone) and one in the Utica shale. *Cryptolithus tessellatus* is not a facies fossil, as its occurrence in this section shows for it is in both dense fine-grained blue limestone and coarsely crystalline gray limestone (coquina rock) in the lower zone, and in the Utica it is in a very fine-grained carbonaceous shale. In northern New York at the eastern end of Lake Ontario, it is found in green, yellow, and brown sandy and calcareous shale, and in sandstone in the Lorraine (Pulaski).

When the Trenton is traced northward from Trenton Falls it is found well exposed along the tributaries entering the Black River from the west. In this region the Cryptolithus bed is no longer seen at the base of the formation, but the middle beds with *Prasopora simulatrix* are the same as at Trenton Falls. At the top, however, a considerable thickness of strata are added, of a kind not seen at Trenton Falls, and containing a fauna not found there. Above thin-bedded limestone containing *Rafinisquina deltoidea*, these beds being the equivalent of the upper strata at Trenton Falls, one finds thick-bedded impure dark gray limestone which on weathering breaks down into a rubbly mass. This limestone contains many gastropods and some other fossils, the most characteristic being *Hormotoma trentonensis*, *Fusispira subfusiformis*, and *Cyclospira bisulcata*.

It is interesting to note that the species which are most characteristic of the upper beds and most of which are not found at Trenton Falls, were described originally from this region. Thus the type-localities of *Fusispira subfusiformis* are Adams, Jefferson County, where only these upper beds are exposed, and Turin, Lewis County. *Trochonema ambigua*, *Fusispira vittata*, and *Cyclospira bisulcata* were all described from specimens obtained at Adams, and *Holopea paludiniformis* and *Subulites elongatus* were both found originally in the higher Trenton strata at Watertown. Of all these species, only the last has been found at Trenton Falls, and in New York they are characteristic of strata above the strata exposed at Trenton Falls, and the highest Trenton limestone exposed in the State.

Ontario.

Crossing into Ontario, the section is practically identical with that in northern New York, except for certain local developments. The strata in the middle of the Trenton remain the same as those at Trenton Falls, but the lower beds do not carry Cryptolithus. The lower beds do, however, show a decided recurrence of Black River conditions and faunas, as high as 100 feet above the base of the formation, so that there is here practically continuous sedimentation after the Leray, the Trenton fauna gradually replacing the Leray fauna. In this respect the section reminds one greatly of Kentucky, as will be seen later.

The section, in descending order, is as follows, the section at Ottawa being taken as typical of the region.

		Feet.
6.	Dark brown to black carbonaceous shale with *Triarthrus spinosus, T. becki, T. glaber, Leptograptus annectans, Glossograptus quadrimucronatus,* and other graptolites. Gloucester formation. (New Name).	50–75
5.	Interstratified limestone and dark shale. Characteristic fossils are *Ogygites canadensis, Oxoplecia calhouni, Zygospira uphami, Plectambonites rugosus,* etc. Collingwood formation.	25–30
4.	Thick-bedded dark gray limestone with very little shale. Characteristic fossils are *Fusispira subfusiformis, F. nobilis,* and many other gastropods, *Cyclospira bisulcata, Strophomena trilobata,* and, in the lower part, *Rafinesquina deltoidea.* Picton formation.	100
3.	Gray limestone, thin-bedded and with much interstratified shale in the lower twenty-five feet, less shaly but not very thick-bedded above. "Prasopora beds" or true Trenton. In the shale at the base *Clitambonites americanus* is the guide fossil, though many others are present. In the strata a short distance above these a profusion of echinoderms are found, among them being *Pleurocystites squamosus, P. filitextus, Agelacrinites inconditus,* and *Comarocystites punctatus. Prasopora simulatrix* is so very abundant throughout these strata that I have usually spoken of them as the Prasopora beds.	100
2.	Coarse-grained light gray thick-bedded limestone, thirty-three feet in thickness, resting upon sixty-six feet of blue to gray fine- to coarse-grained limestone containing great quantities of black chert in layers and flattened cakes. The upper beds contain an abundance of Stromatocerium and Solenopora and in a nearby locality, *Tetradium racemosum.* The lower beds have shaly partings in which great numbers of fine echinoderms have been found, particularly crinoids. Among the characteristic fossils are *Edrioaster bigsbyi* and *Cleiocrinus regius.* Hull formation.	100
1.	Thick-bedded dark gray limestone with partings of shaly limestone containing numerous fossils, among them *Triplecia extans, Phragmolites compressus, Orthis disparalis, Strophomena filitexta,* and *Receptaculites occidentalis.* This formation is not well exposed at Ottawa. Rockland formation.	35

It will be noted that in this section there is a formation added at the top which is even younger than any found in New York and that it is characterized by a fauna differing in a considerable number of species from the fauna found below. The strata containing this fauna are at the base, limestone, but above pass over into dark shale which becomes finally typically "Utica" in facies. The transition from the limestone of the Picton into the limestone of the Collingwood is gradual and some of the species of the Picton continue into the Collingwood; there is probably no break in sedimentation.

Minnesota.

These formations, or at least most of them, can be traced across Ontario to the westward and in Minnesota the following section may be seen (Winchell and Ulrich, 121).

		Feet.
8.	Massive dolomitic limestone with Maclurites and Maclurina. Stewartville dolomite.	50
7.	Fine grained to subcrystalline limestone with some argillaceous layers in the upper portion. Among the fossils are *Rafinesquina deltoidea*, *Zygospira uphami*, *Fusispira nobilis*, *Fusispira inflata*, *Cyclospira bisulcata*, etc.	56
6.	Cherty limestone with *Orthis tricenaria*, *Clitambonites americanus*, *Parastrophia hemiplicata*, etc. Clitambonites bed.	9
5.	Mostly thin-bedded limestone, argillaceous in the lower portion and becoming more pure toward the top.	36
	Zones 7 to 5 belong to the Prosser limestone.	
4.	Blue shales with branching sponges. Fucoid bed.	6
3.	Blue shales with Bryozoa and Ostracoda. Phylloporina beds.	14
2.	Shales with limonite, sometimes oölitic in structure. Many Pelecypoda. Ctenodonta bed.	9
1.	Dark green soft shale with numerous Bryozoa. Rhinidictya bed.	23
	Zones 4 to 1 make up the Decorah shale.	

There are two subdivisions of the Trenton strata in Minnesota which may be correlated directly with formations in Ontario. These are the upper strata of the Prosser limestone, (zone 7 of the section above), and the Clitambonites bed (zone 6). The zone 7, with its large gastropods, particularly the Fusispiras and Trochonemas, *Cyclospira bisulcata, Rafinesquina deltoidea,* and *Strophomena trilobata,* is an exact counterpart of the Picton of Ontario.

The Clitambonites beds of both Ontario and Minnesota are characterized by the same species of Clitambonites and Parastrophia, and there are many more fossils common to the two.

The Decorah shales of Minnesota have been correlated by Dr. Ulrich with the strata above the Leray-Black River and below the cystid beds at Kirkfield, Ontario, and on this point we are in agreement.

The Stewartville dolomite is not present in Ontario, nor have any

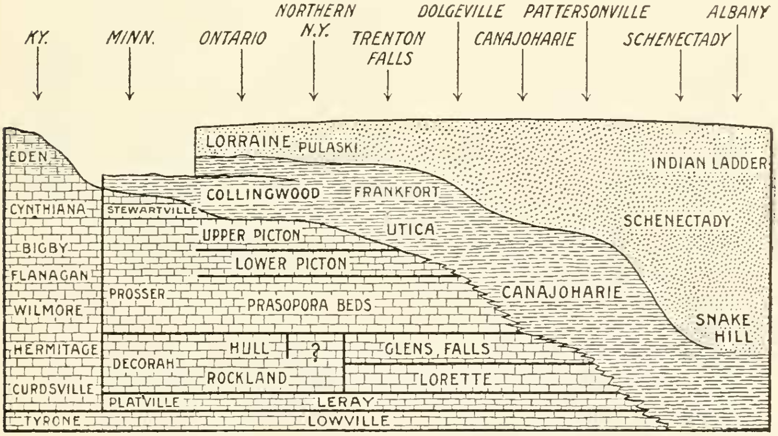

Fig. 1.— Correlation of the sandy and shaly strata of eastern New York with the calcareous strata of the more western localities. The strata represented by the dots are predominantly sandy shales and sandstones, with subordinate amounts of black shale. The next beds below are very fine-grained shales, usually very dark in color, and the remaining strata, represented by the "brick" design, are principally limestone. For Plat'ville, read Platteville.

of its characteristic fossils been found there. In Minnesota a part of the Prosser fauna passes over into the Stewartville, and there does not appear to have been any break in the sedimentary record, so that there was apparently here a persistence of limestone deposition after it had ceased in Ontario.

Reviewing what has been said of the preceding sections, it will be seen how the shales in their westward progress transgressed higher and higher beds of the Trenton series and how, as time went on, their own faunal content became changed, showing that it was not a sudden migration of the sea over a tilted and partially eroded series of earlier deposits, but that the near shore black shales were able constantly to encroach upon the portion of the sea where limestone was forming till it finally progressed over the entire northern and eastern portion of the sea.

If we now turn to the south, we find that in Kentucky and Tennessee, clear water conditions prevailed throughout the Trenton and consequently there were very different faunas, a fact best expressed in the presence there throughout the Trenton of the corals Columnaria and Tetradium.

Kentucky.

The following is a section in central Kentucky, after Foerste (102).

		Feet.
7.	Granular limestone above, argillaceous limestone and clay below. This formation is referred to the Eden by the Kentucky geologists. Along the Ohio River opposite Cincinnati it contains Cryptolithus in abundance and in northern central Kentucky it contains a fauna very closely allied to that of the Eden and Maysville. Cynthiana formation.	40
6.	Granular limestone in the upper five feet, nine feet of dense white limestone below, and twenty to twenty-five feet of fine-grained grayish limestone at the base. The fauna is large, containing many gastropods and pelecypods, several brachiopods, and two species of Tetradium, *T. columnare* and *T. fibratum*. Perrysville formation.	35
5.	Granular limestone above, with seven to ten feet of fine-grained argillaceous limestone below. *Columnaria alveolata* is present in the upper part, and the lower bed is the one from which the Brachiospongia have been obtained. It contains the oldest Platystrophia and Clitambonites found in the Kentucky section. Flanagan formation.	60–70
4.	Granular limestone with Stromatocerium. Benson formation.	35
3.	Argillaceous limestone with interbedded thin clayey layers. *Prasopora simulatrix*, *Rhynchotrema increbescens*, and *Hebertella frankfortensis* appear first at this	

horizon, most of them passing up through the Perrysville. Three species of Fusispira, and other gastropods are present. Wilmore formation. 70

2. Fine-grained limestone alternating with clayey layers of similar thickness. *Heterorthis clytie, Dalmanella fertilis, Leptaena tenuistriata*, and *Cryptolithus tessellatus* are characteristic species. Hermitage formation. 22
1. Granular limestone with cystids, *Edrioaster bigsbyi, Orthis tricenaria, Dinorthis pectinella*, etc. Curdsville formation. 23

On a first survey of the lithological characteristics of the section in central Kentucky, one is impressed by the large amount of light-colored, fine-grained and coarse-grained rather pure limestone and the lack of dark-colored shale.

Columnaria occurs in the Curdsville, Flanagan, and Cynthiana formations, and Tetradium in the Hermitage, Perrysville, and Cynthiana, so that the Wilmore and Benson are the only formations without corals.

Because of the presence of species of Amygdalocystites, Pleurocystites, and Edrioaster in the Curdsville in Kentucky it has become the custom to correlate this zone with the cystid zone of Ontario. Ulrich, and following him, Bassler, have correlated the Prosser of Minnesota with the Curdsville of Kentucky, a correlation not borne out, I think, by the evidence.

The Curdsville fauna of Kentucky is a pure derivative of the Black River, only the echinoderm fauna being added to a rather typical Leray-Black River assemblage of fossils.

In Minnesota the Pleurocystites occur in a very different association. They are found in the lower part of the Fusispira beds (zone 7 of the section above) where they are associated with *Strophomena trilobata, Cyclospira bisulcata,* and *Rafinesquina deltoidea,* all Upper Trenton species in New York and species which are never found so low as the Black River. This zone is also above the Clitambonites bed, which can not be correlated with anything older than the Wilmore of Kentucky.

In Ontario there are three "Curdsville" zones, two above and one below the bed which is correlated with the Clitambonites bed of Minnesota. All are seen in the section at Ottawa, where the zones are separated by seventy-five feet of strata containing two distinct faunules.

The lower zone, to which I have given the formation name Hull, is well exposed at Kirkfield, which locality has become famous for its beautiful crinoids, cystids, and starfishes. Though separated at this locality by about twenty-five feet of strata (Rockland formation) containing a good fauna in which a number of Trenton genera are introduced (Platystrophia, Triplecia, Calymene, etc.), the Hull contains a number of fossils which have survived from the Black River. It is very near the horizon of the Curdsville. At Ottawa this formation contains many echinoderms but very few Pleurocystites, these fossils being abundant in a zone seventy-five feet higher in the section. It was from these higher beds that *Pleurocystites squamosus* and the other species described by Billings were obtained. From this upper bed all the Black River species are absent and the cystids are associated with species of the Clitambonites fauna. In this same section at Ottawa there is a third zone of echinoderms, some forty feet above the middle one, and in the Picton formation. This zone has produced a number of cystids and blastoids associated with *Strophomena trilobata*, *Rafinesquina deltoidea*, and *Cyclospira bisulcata*, and though, so far as I know, no Pleurocystites have been found at this horizon, it is probably the horizon with which the Minnesota cystid bed is to be correlated. In other words, in the Ottawa section there is a lower, a middle, and an upper Trenton Curdsville bed, no one of which is exactly of the age of the Curdsville bed of Kentucky, and affording plain evidence that the echinoderms in themselves are of no value in determining correlations. From a study of the associates of the fossils it is very evident that the Curdsville of Kentucky is most nearly of the same age as the Hull of Ontario, whence it follows that the higher beds in Ontario are younger. The Minnesota "Curdsville" is youngest of all, and to be correlated with the Picton of Ottawa and northern New York, and that is in turn younger than the strata exposed at Trenton Falls. If on the other hand, the Curdsville of Kentucky is to be correlated with the "Curdsville" of Minnesota, then the base of the Kentucky section is above anything seen at Trenton Falls, and not below it.

Pleurocystites also appears in eastern New York and at Montreal, this time in the Glens Falls formation, near the base of the Trenton. These strata are probably of about the same age as the Hull beds of Ontario and the Curdsville of Kentucky though no strict comparison of the faunas is possible.

The second point to be considered in the correlation of the Minnesota and Kentucky sections is the disposition to be made of the group of Fusispiras so characteristic of the Fusispira bed.

Ulrich has said of this fauna: "East of Minnesota we find it well developed, though perhaps occupying only a few inches of limestone, at the base of the Trenton in Northern Michigan, Ontario, Quebec, New York and Northern New Jersey. In the Mohawk Valley in New York, the bed containing this fauna is very thin and only locally present." (119, p. 369.)

The Fusispira fauna in Minnesota is characterized especially by large gastropods, including *Fusispira nobilis, F. inflata, F. ventricosa, F. subfusiformis, F. vittata,* and *Hormotoma trentonensis* and with them are associated *Cyclospira bisulcata, Rafinesquina deltoidea, Strophomena trilobata* and other fossils, though the brachiopods mentioned seem to be found principally just below the real Fusispira zone. In Ontario one finds exactly the same association, at Ottawa, at Picton, Wellington and other places in southern Ontario and at Collingwood on Lake Huron. As I have already pointed out above, this fauna is found in northern New York also at the top of the Trenton, and in sections where one can see the whole Trenton from base to top, as for instance on Roaring Run, south of Watertown, it is clearly seen that the Fusispira beds occupy a considerable thickness, not a few inches, at the top of the Trenton. I have already pointed out above that the typical localities for such of the above species of the Fusispira fauna as were described by Hall are all in the Upper Trenton.

The Fusispira fauna is, in part, so far as relates to its gastropods at least, a recurrent fauna, which fact has not been recognized by Ulrich, and has led to the erroneous correlation of the Minnesotan with other sections. In Minnesota Fusispiras make their first appearance in the Upper Trenton, but in other regions they were introduced with the Black River fauna and recurred at various times. Thus in Kentucky one finds in the Wilmore, *Fusispira subfusiformis, F. angusta,* and *F. angusta subplana,* but its associated fauna contains none of the "guide fossils" found with the Fusispiras in Minnesota. There is a large gastropod fauna, but it is not *the* Fusispira fauna.

In the quotation from Ulrich above, the Fusispira fauna is said to be at the base of the Trenton in northern Michigan, Ontario, Quebec, New York and northern New Jersey. Of northern Michigan I know nothing. Ontario has already been sufficiently discussed. Where in Quebec the Fusispira fauna is developed I can not imagine, though I have an intimate knowledge of the principal localities for the Trenton of that province. In reply to a request for information, Dr. Ulrich wrote me under date of 12 January, 1912, as follows: "The Fusispira fauna was found in New York in the vicinity of Poland, Herkimer

County. Also in the neighborhood of Amsterdam. I have better collections from near Lake Ontario, on Sandy Creek, near Ellisburgh, Jefferson County."

Since receiving this letter I have visited all these localities, the first two of which were already familiar to me from previous work. There can be no doubt that the last locality contains the typical Fusispira fauna, for the strata there are of the very highest Trenton, just beneath the Utica shale, and it is in the immediate vicinity of the places from which the principal species of the Fusispira fauna were originally described. The other two localities are located where only basal Trenton strata are exposed. "The vicinity of Poland" probably means the exposures between Poland and Newport, the localities of the well-known Rathbone Brook section and the "Moshier quarry" in the Leray-Black River. The lower part of the Trenton (Cryptolithus beds) in this section contains some layers with gastropods, but I have found Fusispira here only in the Leray-Black River where it is associated with a number of other gastropods in a large fauna (107).

At Amsterdam the section is practically the same as at Poland. Only the lower part of the Trenton is exposed, and it rests upon a very small thickness of the Leray-Black River, which formation is not very fossiliferous. If any members of the Fusispira fauna are found here, they must be in a very different association from that in Minnesota, and are certainly at a much lower horizon.

The last place mentioned by Ulrich, is in New Jersey, at Jacksonburg, where the formations present are equivalent to those at Amsterdam and Poland in New York and the same remarks will apply to it. Personally I am unable to see in the faunas of any of these localities anything to suggest the Fusispira fauna of Minnesota and even if the Fusispira fauna be there, the section in New York affords ample proof that the Lower Trenton beds with Cryptolithus are below the typical Trenton of Trenton Falls and the Fusispira fauna occurs in the Upper Trenton beds, above the typical Trenton of the Trenton Falls section.

The above discussion is necessary to justify my position in placing the Prosser very much higher in the section than it is placed by other writers.

Central Pennsylvania.

The section in central Pennsylvania at Bellefonte has been described in outline by Professor Collie (100), and has lately been reinvestigated at my suggestion by Mr. R. M. Field, in whose company I was able to spend a few days on the work. The study of the collections is still incomplete, and considerable field-work remains to be done before any satisfactory correlation can be made, but the preliminary results seem to indicate a correlation with the formations in Kentucky rather than with those in New York. The important fact, mentioned before, of the identification of the fauna of the Leray-Black River in the strata just above the pure quarry rock gives a datum plane for correlation. Above this zone, but still in the strata called "Black River" by Collie, is found the fauna with Echinosphaerites, and in the lowest "Trenton" (A 8 of Collie), one finds fossils such as *Cryptolithus tessellatus, Orthis tricenaria,* Dinorthis, and others which suggest the Hermitage of Kentucky. The "Trenton" has a thickness of 600 feet, and at the top, Cryptolithus comes in a second time, as in the Cynthiana of Kentucky. In our present state of knowledge, it must be confessed that the thickness of the section, the general likeness of the faunas, and the two occurrences of Cryptolithus, are the principal bases on which the correlation is made. So far the upper Echinosphaerites zone with Christiania has not been found at Bellefonte, but the general similarities of the sections at Chambersburg and Bellefonte are such that we fully expect work in the intervening areas to establish a fairly secure correlation between them.

GENERAL DISCUSSION OF RUSSIAN EARLY ORDOVICIAN FAUNAS.

The correlations attempted above have been based largely upon stratigraphic position and "guide fossils." It remains to compare in a little more detail the faunas of the strata which have been correlated.

Walchow and Kunda formations.

The part of the correlation which I must most justify to American students is, probably, that in which I agree with most Continental authors, in assigning the Walchow and Kunda formations, B_{II} and B_{III}, to the horizon of the American Beekmantown. Therefore, I wish, in addition to what has already been brought out, to discuss the faunas of these two formations in some detail. Bassler has correlated the two formations, in a general way, with the lower part of the Black

River, and it has been by no means unusual, even among European text-book writers, to consider the upper formation (Orthoceras limestone) as of Black River age, this being primarily due to the abundance of large cephalopods and of trilobites in both the Orthoceras limestone and the Black River limestone. Bassler's argument seems to be based largely upon the state of development rather than on identity of species of the bryozoan fauna, for of eleven species in the Glauconite limestone and fourteen in the Orthoceras limestone, only two in each are identified by him with American species.

Lamansky has listed 142 species and varieties of fossils from these two formations, and Schmidt and Bassler have since added enough more to bring the number to about 186. Of these, seventy-seven are trilobites, forty-five brachiopods, nineteen cystids, twenty-six bryozoans, eleven cephalopods, four pteropods, and four gastropods.

Trilobites.

Eighteen genera of trilobites are listed, and of these, most of the prominent ones, namely, Asaphus, Onchometopus,[1] Niobe, Pseudasaphus, Ptychopyge, Cyrtometopus, Cybele, Pliomera, and Platopolichas, do not occur in America. Of the remaining nine genera, Nileus and Eoharpes are found in the typical Beekmantown, Megalaspis may occur in the Beekmantown, provided the few American species which have been referred to that genus really belong,[2] and Illaenus is common in the Beekmantown, while the other genera, Ceraurus, Remopleurides, Lichas, Pterygometopus and Ampyx make their first appearance in American faunas in the Chazy or later formations. To these five genera belong eighteen species, mostly rare trilobites, and of the eighteen species, eight are confined to the upper of the two formations.

These figures indicate very clearly the total unlikeness of the trilobite faunas of the Beekmantown of America and the Walchow and Kunda of Russia. Of eighteen genera only four are common to the two, nine are entirely unknown in America, and four make their first American appearance in the Chazy. In America, Lichas appears first in the Silurian.

[1] The American species referred to this genus by the writer must probably be included with Brachyaspis.

[2] *Megalaspis beckeri* Slocum is almost certainly not a Megalaspis.

Brachiopoda.

The Brachiopoda are listed by Lamansky under twelve generic names, but here comparisons are less satisfactory as the species have not been studied critically. Orthis as used in this list includes Orthis *s. s.*, and Dalmanella, and should include Platystrophia, two species of which occur, but are not listed by Lamansky. Acritis should also be added. This increases the list to fifteen genera, two of which we may at once drop, Leptaena as being meaningless in the present state of our knowledge of the three species referred to it, and Lingula as being cosmopolitan. Of the thirteen genera then remaining, eight, Porambonites, Lycophoria, Plectella, Pseudocrania, Acritis, Pseudometoptoma, Philhedra, and Siphonotreta, are unknown in the Ordovician of America. Orthis is known from the American Beekmantown, Dalmanella is probably there, though doubts have been cast on some of the species so referred, and Strophomena may be there, but the reported cases are questioned. Clitambonites appears first in the Chazy, and Platystrophia in the Trenton. In passing, it may be said that *Orthis obtusa* Pander, which is very abundant, belongs to an undescribed genus, unknown in America, and that *Orthis parva* Pander, which Wysogorski (57) states can not be a Dalmanella because impunctate, is in reality exceedingly punctate. Orthis is very common and exceedingly variable in these deposits, but all the species agree in having a much lower cardinal area and a much wider delthyrium than the species which we in America know as a typical Orthis (p. ex. *Orthis tricenaria*). *Orthis panderiana* Hall and Clarke, of our Beekmantown, is much more like the typical Orthis of the Walchow.

Bryozoans.

As previously stated, Bassler describes twenty-six species and varieties from these two formations, four species and one variety being identified as common to Russian and American deposits. *Arthroclema armatum* is said to be common to the Walchow and to the Nematopora and Fusispira beds of Minnesota (Upper Trenton). *Dianulites petropolitanus*, which in Russia ranges from the Walchow to the Wesenberg, is also identified in the same upper Trenton strata in Minnesota. *Batostoma fertile* and its variety *circulare* are said to be common to the Kunda formation of Russia and the Stictoporella bed (Black River) of Minnesota. *Hemiphragma irrasum*, found in the

Stictoporella, Rhinidictya, Phylloporina, and Clitambonites beds (Black River to Middle Trenton) of Minnesota, was identified from the Kunda of Russia. These forms are evidently of little value in direct detailed correlation, since the two species found in B_{II} would correlate that formation with the Upper Trenton, while the two found in B_{III} correlate that formation with the Black River and Lower Trenton. One of the species has a range equal to almost the whole Ordovician of Russia, and another has a very long range in America, so that no very valuable conclusions can be derived from them.

In considering the Bryozoa, it must be remembered that as yet only a few specimens belonging to the genus Nicholsonella, have been found in the American Beekmantown, and that the fairly large bryozoan fauna of the Chazy is as yet undescribed. The comparison of the range of genera in America and Russia does not, therefore, mean much, for many of the American genera now supposed to start in the Black River will probably be found to have their beginnings in the Chazy. There are, however, one or two interesting points to be noted in this connection. Bassler distributes the twenty-six species which he describes under eighteen genera (compare with seventy-seven species of trilobites in eighteen genera, and forty-five species of brachiopods in fifteen genera). Of these eighteen genera, only three are not found in America (compare with eight out of eighteen in the trilobites and eight of fifteen in the brachiopods). Three more are very peculiar, in that their American range begins much later than in Russia. One of them is known in this country from the Richmond to the Mississippian, another from the Niagara to the Coal Measures, and the third is wholly Devonian and Mississippian. A single one is found in the American Beekmantown, and the remaining eleven are known from the Stones River or Black River to the Richmond, excepting for one or two which do not start till the Middle or Upper Trenton. Looking over the table showing the range of the various species in Russia, we find that four species are confined to B_{II}, one is confined to B_{II} and B_{III}, nine are found only in B_{III}, eight pass from B into C, but do not extend further, and that three begin in B and continue into D, E, or F. Thus, among the Bryozoa, there are only five species common to B_{II} and B_{III}, and of these only one does not continue into C, while there are eleven common to B and C, which is very unlike the condition which obtains among the other classes. For instance, in the seventy-seven species of trilobites, nineteen are common to B_{II} and B_{III}, and only thirteen pass from B into C, and some of these cases must be considered as doubtful, since they come from that district on the

Walchow where the boundary between B_{III} and C_1 is indefinite. Still it is evident that thirteen out of seventy-seven is a much smaller proportion than eleven out of twenty-six. The only conclusion which it is possible to draw from the above rather remarkable array of evidence derived from the bryozoans is that both the species and genera have too great a vertical range to allow their use in direct correlations.

Cystidea.

Lamansky lists fifteen species of cystids, belonging to six genera (if Bolboporites can be called a genus), but he places no particular specific names after Cheirocrinus. As a matter of fact there are a considerable number of species of cystids not enumerated by Lamansky, but that does not affect the present purpose.

Of the six genera listed, three are unknown in America. Of the remaining three, Glyptocystites and Bolboporites appear in the Chazy, and Cheirocrinus in the Trenton. As with the Bryozoa, it must be remembered that the cystidean fauna of the Beekmantown is unknown. There is plenty of proof that cystideans were present, but most of our Beekmantown rocks are lithologically ill adapted either for the preservation or recovery of fossils.

Cephalopods.

Vaginoceras is of course the common genus in the Kunda, and that genus is represented in America by a single species found in the Chazy. Other genera, like Estonioceras and Planctoceras are unknown here.

Gastropods.

Gastropods make their first appearance in Russia in the Kunda, and the variety there is small. Of the four genera, two, Maclurites and Sinuites, are found in the Beekmantown, while Raphistoma appears first in the Chazy and Salpingostoma in the Stones River.

The fauna as a whole.

Bringing together what has been said above, it appears that out of the 186 species considered, five, all Bryozoa, have been considered as identical with species found in America, and these appear in the two countries in reverse order, and thus have no significance. Of the genera, including organisms of all kinds except the Bryozoa, about half are not found in America. Of the genera common to the two countries, a few make their first appearance in America in the Beekmantown, a much larger proportion first appear in the Chazy or Stones River, and a few do not appear in America till Middle or late Trenton or even later. It is pointed out, however, that even in the case of certain of the genera reputed to be in both countries, the Russian representatives differ in marked ways from American species, and closer research is bound to show greater differences instead of greater likeness between the faunas of the two countries.

The fauna of the American Beekmantown is very imperfectly known, but the classes of fossils so far as relative abundance is concerned, are ranked in the order of: — first, cephalopods; second, gastropods; third, trilobites; fourth, ostracods; and finally brachiopods, cystids, and bryozoans, all in small numbers. On the other hand, the Walchow and Kunda formations have great numbers of trilobites and brachiopods, many cystids, cephalopods, and bryozoans, very few gastropods, a few ostracods, and crinoids. The two groups agree in the absence of pelecypods and corals.

If there were no other evidence than that afforded by the time of the first appearance of certain genera in Russia and America, it might well happen that the Walchow and Kunda formations might be correlated with the Chazy, but I do not see that they could be correlated with any younger strata. The comparison of the Russian with the Scandinavian sections, however, places such a correlation out of the question, and when one compares the faunas of these zones with the fauna of the Ceratopyge formation of Scandinavia, he realizes the antiquity of many of the groups, especially of the trilobites. Megalaspis, which is almost entirely confined to the Walchow and Kunda in Russia, is well represented in the Ceratopyge limestone of Scandinavia, one species being apparently common to the two formations and regions. Symphysurus, Nileus, Niobe, Eoharpes, and Ampyx are other genera connecting these formations with the Ceratopyge limestone, and even species of Nileus and Niobe are said to be common to the two.

On *a priori* grounds, we would not expect the Walchow and Kunda faunas to have much in common with the Beekmantown, if they are of the same age. The American fauna is an autochthonous one developed in the interior continental sea, out of the late Cambrian fauna. The fauna in Esthonia was, on the other hand, an invading fauna which was derived primarily from the Ceratopyge fauna of

Scandinavia, but that in turn though it received certain contributions from the late Cambrian faunas of the region in which it developed, owed much of its richness to types developed further south in the Tremadoc of Bohemia, France, and England. Having once gotten a foothold in northern Europe, the fauna developed very rapidly there, but apparently in an enclosed basin, for this fauna, as a whole, is unknown outside Scandinavia and Russia. Here, however, the factor of bottom control must be taken into account. As we have shown (p. 222), it is generally recognized that the black shales with the Didymograptus-Tetragraptus-Phyllograptus fauna were deposited at the same time as the "Orthoceras limestone," and in the same sea, but under different physical conditions. As is well known, the graptolite faunas did migrate, and very widely, but they did not carry the bottom fauna with them. If we adopt the rather generally accepted opinion that the graptolites were pelagic animals, supported either by floats or by their attachment to floating bodies such as sea weeds, we may conceive that the graptolites may have been distributed within a very short time, by the power of ocean currents, over very wide areas, while the influence of a strong current or of a cold current, impinging upon headlands, or the presence of vast expanses of sandy or muddy bottoms, may have long delayed the migration of bottom-living animals. We seem to have an excellent example of this in the case of Shumardia and certain associated species of the Ceratopyge limestone. In Sweden and Norway, Shumardia is rather abundant in the shale and limestone making up the Ceratopyge zone, and this zone is above the shale with *Dictyonema flabelliforme*, but below that of Tetragraptus and Phyllograptus. The Shumardia limestone of America, however, (at Point Lévis) is very high in the Tetragraptus-Phyllograptus series, so high even as the beginning of the range of Diplograptus. This case is the more striking since there are several species of the Scandinavian Shumardia-Ceratopyge fauna (*Shumardia pusilla* (Sars), *Agnostus sidenbladhi* Linnarsson, and *Symphysurus elongatus* Moberg and Segerberg) in this limestone high in the Lévis.

Under these conditions, if these species of the Ceratopyge fauna could not arrive in America until late Beekmantown, it is not surprising that many genera which originated in Europe during Beekmantown time, should not have arrived in America till the Chazy. I do not wish to be understood to advocate a general principle that homotaxial formations of separated continents are really one stage apart in age, but each particular case must be decided on its own merits.

Wierland group.

This series, held together by the presence throughout of *Echinosphaerites aurantium*, shows a decided change of faunas from bottom to top. The fauna of the oldest formation, the Dubowiki, is dominated by its asaphids, but these trilobites immediately lose their importance, and though they continue through the remainder of the Ordovician, they are present in limited variety and numbers. As previously stated, there are thirteen species which pass over from the Walchow and Kunda into the Dubowiki, but very few of them survive beyond this formation.

The Wierland fauna is, however, in general, an outgrowth of that which preceded it in the same area. Among the trilobites, notable new arrivals in this group are: — Chasmops, Sphaerocoryphe, Pseudosphaerexochus, Sphaerexochus, Acidaspis, Hoplolichas, Homolichas, Cyphaspis, Lonchodomas, and Ogygites (Basilicus of Schmidt). All of these genera, with the exception of Acidaspis and Cyphaspis could have arisen as modifications of types already in this region, so that we have, as true invaders only these two genera.

Among the brachiopods the important new genera are Christiania and Oxoplecia. The place of origin of these genera is unknown, but from their short ranges and limited variety in Russia, it seems probable that they are present there as migrants. Other brachipods introduced here are Plectambonites and Rafinesquina, but the dominant forms are the Clitambonites and Porambonites which continue from the formations below.

Among the gastropods, Bucania, Cymbularia, Eccyliopterus, Salpingostoma, and Subulites make their appearance first in this formation; while of the echinoderms, we find here the oldest species of Caryocystites, Echinosphaerites, Cryptocrinites, Cystoblastus, Cyathocystis, Hemicosmites, Hybocrinus, and Protocrinites. Among the sponges, Receptaculites is introduced at this time.

In running over this list of genera newly introduced into the Russian Ordovician during Wierland time, we are struck by the fact that we are here dealing with more familiar genera. Barring some of the cystids and one or two other genera, all these genera are known in America, and most of them from the Middle Ordovician. The greater part of these genera seem to have developed in the North European basin and to have migrated thence to America.

Certain of the genera are, in America, restricted to a belt along the eastern Appalachians and to a small area in western Tennessee and Missouri (Kimmswick of Missouri), and do not occur in the usual Ordovician fauna of the great interior basin. The eastern Appalachian belt extends from Gaspé to Alabama, and includes the "Trenton" at Percé, the Quebec City at Quebec, the "Trenton" of southeastern Quebec, the Chazy and Rysedorph of New York, the Chambersburg of Pennsylvania, the Liberty Hall and Murat of central Virginia, the Holston, Ottosee, Lenoir, and Athens of southwestern Virginia and eastern Tennessee, and the "Trenton" of Alabama. This series includes formations of various ages from Chazy to Upper Trenton.

Russian genera which in America are restricted to the strata mentioned above are Sphaerexochus, Lonchodomas, Christiania, Oxoplecia, and Echinosphaerites. Genera prominent in this group, but only sparingly represented in the interior Ordovician are, Pseudosphaerexochus, Remopleurides, and Sphaerocoryphe.

Of the other genera introduced during Wierland time, Ogygites does not appear in America till late Trenton (Collingwood), Cymbularia is unknown, as are also Cryptocrinites, Cystoblastus, Cyathocystis, Hemicosmites, and Protocrinites. The other genera are more or less common throughout the Middle Ordovician faunas of America.

Some of the more striking of the Wierland guide fossils are absent from the Chazy, thus preventing what seems otherwise a very satisfactory direct correlation. These are Echinosphaerites, Christiania, and Oxoplecia. The fauna of the Chazy is, in fact, a curious mixture of native and immigrant types. All its large molluscan fauna is probably derived directly from the Beekmantown fauna, and most of its brachiopods are also American in origin. There is certainly nothing in northern Europe like its great profusion of rhynchonelloids, and its Orthidae and Strophomenidae may as well be native types as invaders. Even Camarella, the Chazy representative of the Porambonitidae, is probably of American stock, and does not really represent the Russian Porambonites. In Clitambonites, however, we have a true immigrant, which did very well for a time.

When we come to the trilobites, however, we begin to see the invaders. In the list we notice not only certain native genera, Bathyurellus, Isotelus, Isoteloides, Thaleops, and Glaphurus, but also many others, which are actually Russian or derived from Russian stocks. These are, *Russian:* — Eoharpes, Lonchodomas, Remopleurides, Nileus, Ceraurus, Pseudosphaerexochus, Nieszkowskia, Sphaerocoryphe, Sphaerexochus, and Pterygometopus; derived from *Russian stock:* — Cybeloides, Pliomerops, Vogdesia, and Heliomera.

These genera may be divided into two groups, first those appearing first in the Walchow and Kunda in Russia, and second, those making their first appearance in the Wierland in Russia. In the first group we find Eoharpes (also in Beekmantown), Remopleurides, Nileus, Ceraurus, Nieszkowskia, and Pterygometopus. In the second group are only Lonchodomas, Pseudosphaerexochus, Sphaerexochus, and Sphaerocoryphe. Cybeloides, Pliomerops, Vogdesia, and Heliomera are all derived from forms appearing first in the lower group in Russia.

From this analysis of the Chazy fauna it appears that, while the fauna is in very large proportion of American origin, it has present in it a considerable Russian element which is largely derived from genera present in the Walchow and Kunda formations. Why certain genera such as Echinosphaerites, Oxoplecia, Plectambonites, and Christiania from Russia, and Tretaspis, Nidulites, and Agnostus from Scandinavia, which reached North America somewhere about this time, did not get into the typical Chazy is a perplexing question. So far as bottom control is concerned, there seems to have been no barrier, and only two possible explanations occur, namely, either their natural habitat was fully occupied, or they did not reach America till later than the time of the typical Chazy; the latter explanation seems, in view of all the facts, the more probable.

DETAILED SECTIONS IN RUSSIA.

Sections arranged in order from east to west.

Section on the Walchow. (Given by Lamansky (29)).

$B_{III\gamma}$. Thick-bedded compact limestone at Sapolek and Bylstchina, and at the base of the quarries at St. Michael Archangel. 6 meters = 18.35 m.

$B_{III\beta}$. Rusty and spotted limestone at the base, followed by one or more layers of "Linsenschicht," these being succeeded by red and yellow spotted layers. The Linsenschicht is one meter above the base. 3.5 m. = 12.35 m.

$B_{III\alpha}$. Bluish green limestone with fine-grained glauconite at the base, but none above. 3 m. = 8.85 m.

$B_{II\gamma}$. Compact limestone with some glauconite. Loses compactness quickly on weathering. 2.4 to 2.7 m. = 5.85 m.

$B_{II\beta}$. Thin-bedded limestone with red and yellow spots. Very little glauconite. 1.8 m. = 3.45 m.

$B_{II\alpha}$. Thick-bedded, red, yellow, violet, and gray-green limestone. 1.65 to 1.80 m. = 1.65 m.

SECTION ON THE WALCHOW. (Measured by the writer).

The highest beds are exposed in the quarries at Dubowiki. Zones 11 to 9 were measured near the steamboat landing at St. Michael Archangel, and the remainder of the section on the eastern bank of the Walchow opposite Iswos.

11. Light gray to yellowish magnesian limestone in beds one inch to one foot in thickness. Some layers are fine grained and dense, while others are porous, the fossils occurring as hollow moulds. *Christiania oblonga* common and characteristic. Reval formation. 25 ft. = 112 ft.±
10. Soft gray limestone which breaks down readily to a sticky calcareous mud. Entire trilobites and other perfect fossils common. *Echinosphaerites aurantium* abundant.
    Dubowiki formation. Base not exposed. 14 ft. = 87 ft.±
9. Concealed to river level. 23 ft. = 73 ft.±
    (According to the thickness given by Lamansky the greater part of the concealed interval here would be filled by the "Orthoceras" limestone (Kunda formation)).
8. Red and green limestone enclosing the "Lower Linsenschicht." 3 ft. = 50 ft.
7. Thin-bedded limestone and shale, with 3 feet of rather solid limestone at the top. $B_{II\delta}$ ($B_{III\alpha}$ of Lamansky). 9 ft. = 47 ft.
6. Thick-bedded gray limestone with shaly partings. ($B_{II\gamma}$) 10 ft. 6 in. = 38 ft.
5. Thin-bedded, shaly limestone. ($B_{II\beta}$). 5 ft. 6 in. = 27 ft. 6 in.
4. Heavy-bedded red limestone with abundant glauconite and echinoderm fragments. ($B_{II\alpha}$). 6 ft. = 22 ft.
3. Sandy shale. 1 ft. = 16 ft.
    Zones 3–7, and the lower part of zone 8, below the Linsenschicht, belong to the Walchow formation.
2. Concealed. 3 ft. = 15 ft.
1. White and gray sandstone to the river's edge. Zones 1 and 2 belong to the Packerort formation. 12 ft. = 12 ft.

River Lawa at Wassilkowa. (Measured by the writer).

9. Thin, irregularly bedded, gray limestone and shale. 20 ft. = 72 ft.
8. Bright red and green variegated limestone in thin beds. $B_{II\delta}$. ($B_{III\alpha}$ (partim) of Lamansky). 4 ft. = 52 ft.
7. Thick-bedded light, blue-gray limestone. ($B_{II\gamma}$). 11 ft. = 48 ft.
6. Thin-bedded, irregular, blue limestone with thick shaly partings. ($B_{II\beta}$). 13 ft. = 37 ft.
5. Heavy-bedded red and green limestone with few fossils. ($B_{II\alpha}$). 6 ft. = 24 ft.
4. Green sand and clay. (Glauconite sand). 6 ft. = 18 ft.
   Zones 4 to 8 and the lower part of 9 make up the Walchow formation. The "Linsenschicht" is present in 9, but unfortunately I did not note its exact position.
3. Black shale. (Dictyonema shale). 1 ft. = 12 ft.
2. White, gray, and yellow sand, very irregularly bedded. It crumbles readily at the touch and contains numerous specimens of *Obolus apollinis* along the planes of cross-bedding. Zones 2 and 3 represent the Packerort formation. 10 ft. = 11 ft.
1. Very hard red sandstone, base not seen. 1 ft. = 1 ft.

Papowka, south of Petrograd. (Measured by the writer).

9. Thick-bedded, gray, fine-grained limestone with numerous Orthoceratites. It contains two red layers, each one foot in thickness. 18 ft. = 57 ft.
8. Red limestone full of Orthoceratites. 1 ft. = 39 ft.
7. Heavy-bedded dolomitic limestone which contains cavities from which fossils have been dissolved. Orthoceratites in top foot. 7 ft. = 38 ft.
6. Shaly limestone with "linsen." 5 in. = 31 ft.
   Zones 6–9 represent the Kunda formation.
5. Thin-bedded limestone with much clay and shale. 12 ft. = 30 ft. 6 in.
4. Thick-bedded green and red limestone. 7 ft. = 18 ft. 6 in.
3. Green sandy shale. 1 ft. = 11 ft. 6 in.
   Zones 3–5 represent the Walchow formation.
2. Black shale with only microscopic fossils. 4 ft. 6 in. = 10 ft. 6 in.

1. Green, white, and red sandstone with numerous fragments of Obolus. Base not seen. 6 ft. = 6 ft.
   Zones 1 and 2 represent the Packerort formation.

SECTION AT NARWA. (Given by Schmidt (47) in the Guide for the excursions of the St. Petersburg meeting of the International Geological Congress).

$C_{1\beta}$.	Echinosphaeritenkalk. Dolomite.	3.0 m. = 16.9 m.
$C_{1\alpha}$.	Upper Linsenschicht.	.3 m. = 13.9 m.
$B_{III\beta}$.	Vaginoceras limestone. Dolomite.	3.0 m. = 13.6 m.
$B_{III\alpha}$.	Lower Linsenschicht.	.3 m. = 10.6 m.
B_{II}.	Glauconite limestone.	3.3 m. = 10.3 m.
B_{I}.	Glauconite sandstone with concretions of bituminous limestone with Dictyonema.	.2 m. = 7. m.
A_{III}.	Red Obolus sandstone showing cross-bedding.	2.6 m. = 6.8 m.
A_{II}.	White fucoidal sandstone with sand concretions.	4.2 m. = 4.2 m.

NARWA. (Measured by the writer). Plate 6.

8. Gray limestone, dolomitic, heavy-bedded, and with few fossils at the top, thin-bedded and with numerous Orthoceratites in the lower portion. 10 ft. = 36 ft. 10 in.
7. Linsenschicht. 15 in. = 26 ft. 10 in.
   Zones 7 and 8 represent the Kunda formation.
6. Hard thick-bedded gray limestone. 3 ft. = 25 ft. 7 in.
5. Impure red limestone with numerous *M. planilimbata*. Top layer a much weathered rusty one, full of holes. 8 ft. = 22 ft. 7 in.
4. Red clay-shale. 3 in. = 14 ft. 7 in.
3. Green clayey sand. 4 in. = 14 ft. 4 in.
   Zones 3–6 represent the Walchow formation.
2. Yellow, white and reddish massive and cross-bedded sandstone with very numerous Obolus. At the base is a layer of rounded, hard, sandstone pebbles, three, four, and ten inches in diameter. Much pyrites in lower two or three feet, sometimes in hard layers. 11 ft. = 14 ft.
   Zone 2 represents the Packerort formation.
1. Almost white, thin-bedded sandstone. Base not seen. 3 ft. = 3 ft.
   Zone 1 represents the Esthonia formation.

Asserien. (Zones 16 to 13 are well shown in the quarries and along the railroad about two miles south of the cement plant at Asserien. Zones 13 to 1 are well exposed at and below the large quarry at the edge of the cliff about a mile west of the plant. Measured by Dr. Twenhofel and the writer).

16. Fine-grained magnesian limestone in layers one to three inches thick. Very few fossils. 6 ft. = 76 ft. 1 in.
15. Thick-bedded, fine-grained compact magnesian limestone with an abundance of Orthoceratites in the lower three feet. Some layers are porous and show open moulds of fossils. 8 ft. = 70 ft. 1 in.
    Zones 15 and 16 belong to the Reval formation.
14. Thick- and thin-bedded gray limestone without much shale. Echinosphaerites especially abundant in the lower part. 7 ft. 6 in. = 62 ft. 1 in.
13. Light gray, rather thick-bedded limestone without shale, but becoming soft and shaly on weathering. This zone contains more or less "linsen" throughout, but they are especially abundant in the lower three feet. 8 ft. = 54 ft. 7 in.
    Zones 13 and 14 make up the Dubowiki formation.
12. Thick- and thin-bedded gray limestone which becomes soft and shaly on weathering. Many Vaginoceras present. 14 ft. 8 in. = 46 ft. 7 in.
11. Lower "Linsenschicht." 9 in. = 31 ft. 11 in.
    Zones 11 and 12 represent the Kunda formation.
10. Thick-bedded gray limestone. 3 ft. 6 in. = 31 ft. 2 in.
9. Thin-bedded limestone and shale. 6 in. = 27 ft. 8 in.
8. Thick-bedded, hard, reddish limestone with glauconite. 3 ft. 6 in. = 27 ft. 2 in.
7. Clay and limestone. 8 in. = 23 ft. 8 in.
6. Green clay and sandstone. 6 ft. 3 in. = 23 ft. 0 in.
    Zones 6 to 10 form the Walchow formation.
5. Thin-bedded, soft, yellowish clay-shale. 4 ft. = 16 ft. 9 in.
4. Red and yellow limonite. 3 in. = 12 ft. 9 in.
3. Thin-bedded black shale with thin layers of sandstone in the lower half. 7 ft. = 12 ft. 6 in.
2. Light yellow and red cross-bedded sandstone, with lenses of thin, black shale in layers one fourth to one inch in thickness and with black deposits on the bedding planes. 3 ft. 3 in. = 5 ft. 6 in.

1. Yellow and white sandstone with numerous Obolus, one layer. 2 ft. 3 in. = 2 ft. 3 in.
Zones 1–5 represent the Packerort formation.
Concealed to water-level.

ONTIKA. (Top 206 ft. above sea-level. Measured by Dr. Twenhofel and the writer).

11. Thin-bedded soft limestone with *Echinosphaerites aurantium*. 5 ft. = 78 ft. 5 in.
10. Thin-bedded light gray limestone with numerous Orthoceratites and many small "linsen." Upper Linsenschicht. 7 ft. 6 in. = 73 ft. 5 in.
Zones 10 and 11 represent the Dubowiki formation.
9. Thin-bedded light gray shaly limestone with numerous Orthoceratites. A nine inch shaly parting is present four ft. above the base. 18 ft. 6 in. = 65 ft. 11 in.
8. Lower Linsenschicht. 8 in. = 47 ft. 5 in.
Zones 8 and 9 represent the Kunda formation.
7. Heavy-bedded gray limestone with nine inches of shale at top. 5 ft. = 46 ft. 9 in.
6. Thin-bedded nodular and shaly limestone 6 in. = 41 ft. 9 in.
5. Heavy-bedded reddish limestone with green patches, weathering yellowish. 4 ft. 9 in. = 41 ft. 3 in.
4. Green sandy shale. 4 ft. = 36 ft. 6 in.
Zones 4 to 7 represent the Walchow formation.
3. Hard red limonite layer. 3 in. = 32 ft. 6 in.
2. Black shale, no fossils seen. 7 ft. 3 in. = 32 ft. 3 in.
1. Cross-bedded reddish and white sandstone which disintegrates to loose sand. Base not seen. 25 ft. = 25 ft.
Zones 1 to 3 represent the Packerort formation.
Concealed to water, 127 ft.

CATHERINE PARK, REVAL. (Measured by the writer).

7 Thin-bedded often shaly limestone. The highest layers in the quarries. Echinosphaerites and other cystids common. Kuckers formation. 4 ft. = 47 ft.
6. Light gray compact fine-grained limestone in beds 8 to 15 inches in thickness. Fossils are very rare. Certain layers contain vertical, tube-like fillings suggesting borings. Largely quarried. 28 ft. = 43 ft.

5. Upper Linsenschicht. 1 ft. = 15 ft.
Zones 5 and 6 represent the Reval formation.
4. Two and one half feet of gray limestone with one foot of yellowish dolomite below it. 3 ft. 6 in. = 14 ft.
3. Conglomerate with pebbles of green glauconitic limestone. 6 in. = 10 ft. 6 in.
Zones 3 and 4 represent the Kunda formation.
2. Green glauconitic limestone with most glauconite in the top layer. 7 ft. = 10 ft.
1. Red calcareous sandstone with glauconite grains. Base not seen. 3 ft. = 3 ft.
Zones 1 and 2 represent the Walchow formation.

CHURCH JEGELECHT. (Village Joa on the Jaggoul road, west of Reval. Section by Schmidt (47)).

Upper Linsenschicht.	.3 m. = 8.0 m.
Vaginoceras limestone.	3.2 m. = 7.7 m.
Lower Linsenschicht.	.2 m. = 4.5 m.
Glauconite limestone.	3.1 m. = 4.3 m.
Glauconite sandstone.	.8 m. = 1.2 m.
Dictyonema shale. Base not seen.	.4 m. = .4 m.

BELOW PACKERORT LIGHT-HOUSE. (Two miles north of Baltishport. Measured by the writer). Plate 7.

10. Heavy-bedded dolomitic limestone with few fossils. Weathers dull yellow. Best exposed in the neighborhood of Baltishport. Top not seen. 25 ft. = 80 ft. 1 in.
9. Linsenschicht. 10 in. = 55 ft. 1 in.
Zones 9 and 10 represent the Reval formation.
8. Thick-bedded limestone, the bottom layer full of pebbles of limestone and irregular fragments of phosphatic shale. Kunda formation. 3 ft. 6 in. = 54 ft. 3 in.
7. Thin-bedded limestone and shale. 1 ft. 3 in. = 50 ft. 9 in.
6. Green limestone, very full of glauconite, especially at the base. 2 ft. 6 in. = 49 ft. 6 in.
5. Soft, green sandstone. 11 ft. = 47 ft.
Zones 5 to 7 represent the Walchow formation.
4. Dark clay-shale, weathering to a light gray. Some layers contain numerous graptolites. The shale rests

in hollows in the sandstone below and the strata bend up and down with the irregularities of the subjacent surface. At the base is a bed of limonite two to three inches in thickness. 18 to 13 ft. = 36 ft.

3. Thick, irregularly cross-bedded sandstone with some specimens of Obolus in the upper layer. Thickness variable. 5 to 10 ft. = 23 ft.

2. Thin strata of black shale alternating with layers of yellow or red sandstone. The shale is in beds one to ten inches thick and is similar in character to that above. The basal portion consists of conglomerate with boulders of sandstone from one to five feet in diameter, and also small pebbles cemented together by limonite and pyrite. 5 ft. = 13 ft.

Zones 2 to 4 represent the Packerort formation.

1. Hard, white, coarse-grained sandstone. Base not seen. Top of Esthonia formation. 8 ft. = 8 ft.

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In the list which follows I have enumerated all the works consulted during the preparation of this report, either as to the geology or the identification of fossils. I have not attempted a full bibliography, but, in the case of Russia, have added a few titles which I have not seen, but which are referred to as authorities for certain statements obtained from papers I have seen.

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